Mission Readiness Review (MRR)

Rick Pickering
EOS Aura Project Manager

4 May 2004

Agenda

- **Introduction - Rick Pickering**
- **Science Overview/Team Readiness - Mark Schoeberl**
- **Mission Summary - Rick Pickering**
- **Satellite Readiness - Rick Pickering**
  - Flight Software IV&V - Marcus Fisher
- **Ground System Readiness - Carolyn Dent**
- **Integrated Independent Review Team Assessment - Dennis Dillman**
- **Launch Vehicle/Range Readiness - Dave Breedlove**
- **Launch Vehicle Independent Assessment - Dawn Elliott**
- **Code 200 Readiness - Ray Rubilotta**
- **Public Affairs - Lynn Chandler**
- **Program Manager's Assessment - Dave Scheve**
- **Wrap-up/Action Items**

Mission Readiness Review (MRR)

Mission Summary and Satellite Readiness

Rick Pickering
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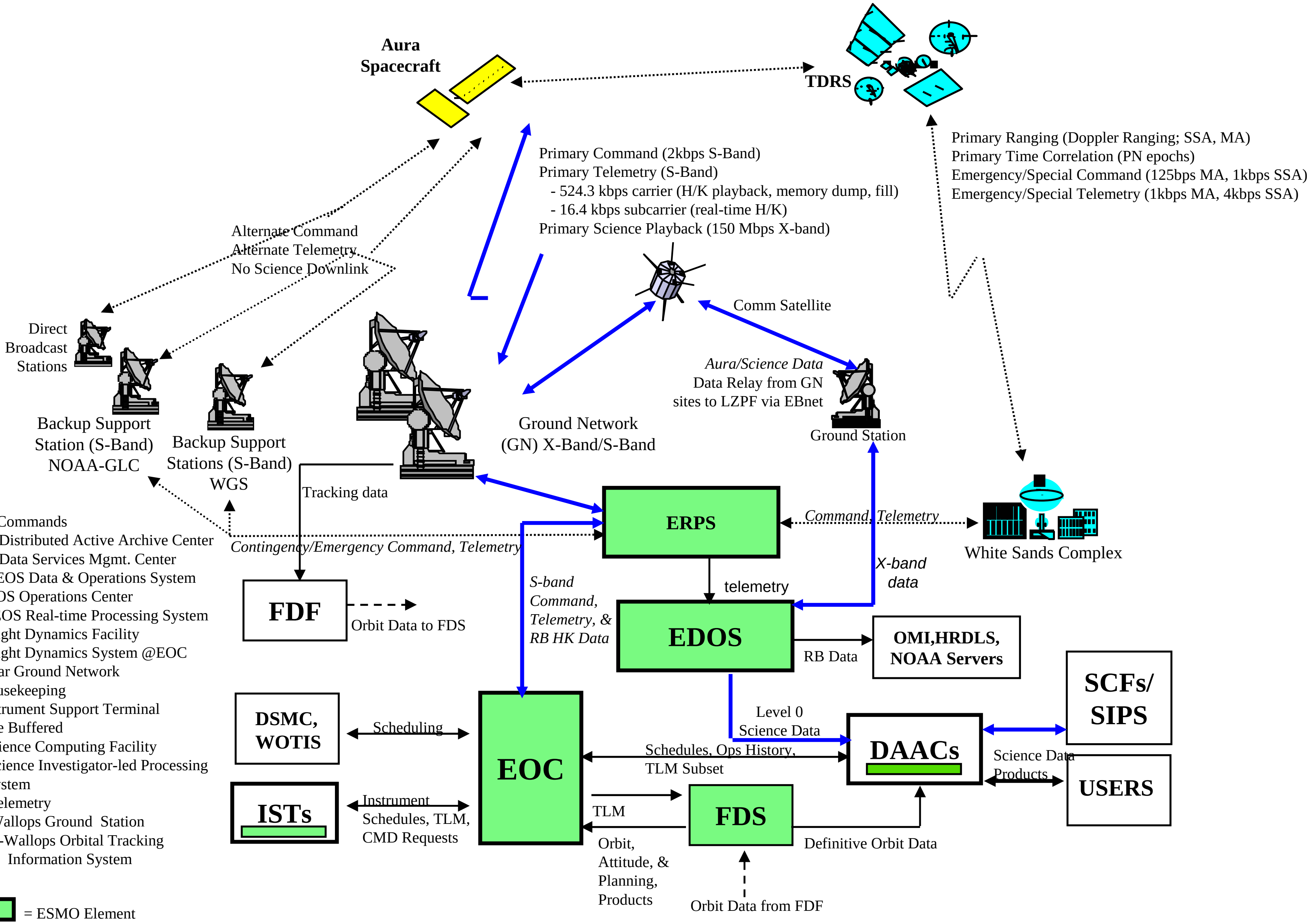
Mission Summary

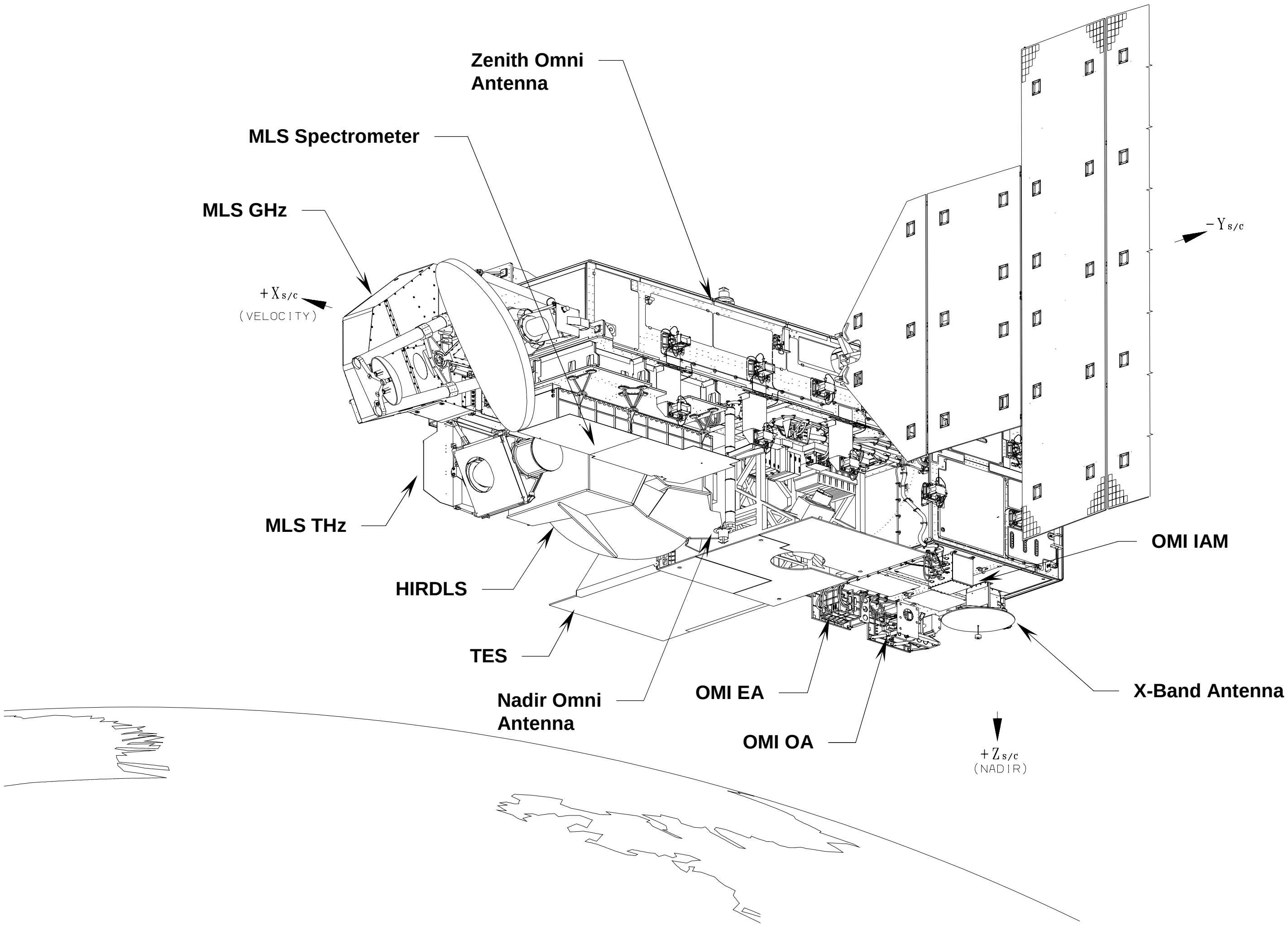
Aura Mission Architecture



CMDs-Commands
DAAC-Distributed Active Archive Center
DSMC-Data Services Mgmt. Center
EDOS-EOS Data & Operations System
EOC-EOS Operations Center
ERPS-EOS Real-time Processing System
FDF-Flight Dynamics Facility
FDS-Flight Dynamics System @EOC
GN-Polar Ground Network
HK-Housekeeping
IST-Instrument Support Terminal
RB-Rate Buffered
SCF-Science Computing Facility
SIPS-Science Investigator-led Processing System
TLM-Telemetry
WGS-Wallops Ground Station
WOTIS-Wallops Orbital Tracking Information System

= ESMO Element

EOS Aura Satellite



EOS Aura System

- **EOS Aura Spacecraft**
  - Built by Northrop Grumman Space Technology (NGST), Redondo Beach, CA
  - Three-axis stabilized platform designed to carry the four Aura instruments and provide support functions of power generation, thermal control, communications, and data storage for instruments and spacecraft
- **Instruments**
  - High Resolution Dynamics Limb Sounder (HIRDLS) -
    - » University of Colorado, Boulder (UCB)
    - » Lockheed Martin Space Systems
    - » U.K. Natural Environment Research Council
  - Microwave Limb Sounder (MLS) - JPL
  - Ozone Monitoring Instrument (OMI) - The Netherland's Agency for Aerospace Programs (NIVR) and the Finnish Meteorological Institute (FMI)
  - Tropospheric Emission Spectrometer (TES) - JPL

Aura Ground System Elements

- **EOS Mission Operations System (EMOS)**
- **EOS Real-time Processing System (ERPS)**
- **Flight Dynamics System (FDS)**
- **EOS Mission Systems Network (EMSnet)**
- **EOS Data and Operations System (EDOS)**
- **Institutional Support: Space Network(SN)/TDRSS, Ground Network (GN)--Polar Ground Stations and WGS, NISN, Flight Dynamics Facility**
- **Distributed Active Archive Centers (DAACs)**
- **Science Computing Facilities (SCFs)/Science Investigator-led Processing System (SIPS)**

Launch Commit Criteria

The following system minimum functions shall be operational at launch:

- **VAFB --** Must have voice communications to GSFC (black phone sufficient); telemetry from VAFB to EOC <u>not</u> required
- **Space Network (SN) --** SN including WSGT and STGT configured and operational to support seven hours near-continuous SN SSA services post-launch
- **SGS, SKS or SG3 --** 1 Svalbard antenna and associated S-band equipment strings operational for command and telemetry
- **EOS Operations Center (EOC)**
  - Must be able to process telemetry and send commands
  - Must be able to provide real-time attitude determination
  - Must be able to generate command loads
- **Flight Dynamics Facility --** Must be able to provide the initial vector to the EOC
- **NASA Integrated Services Network (NISN) --** All voice and data lines operational between the EOC and other Ground Commit Elements
- **Spacecraft --** Launch Commit Criteria are defined in NGST document D37494

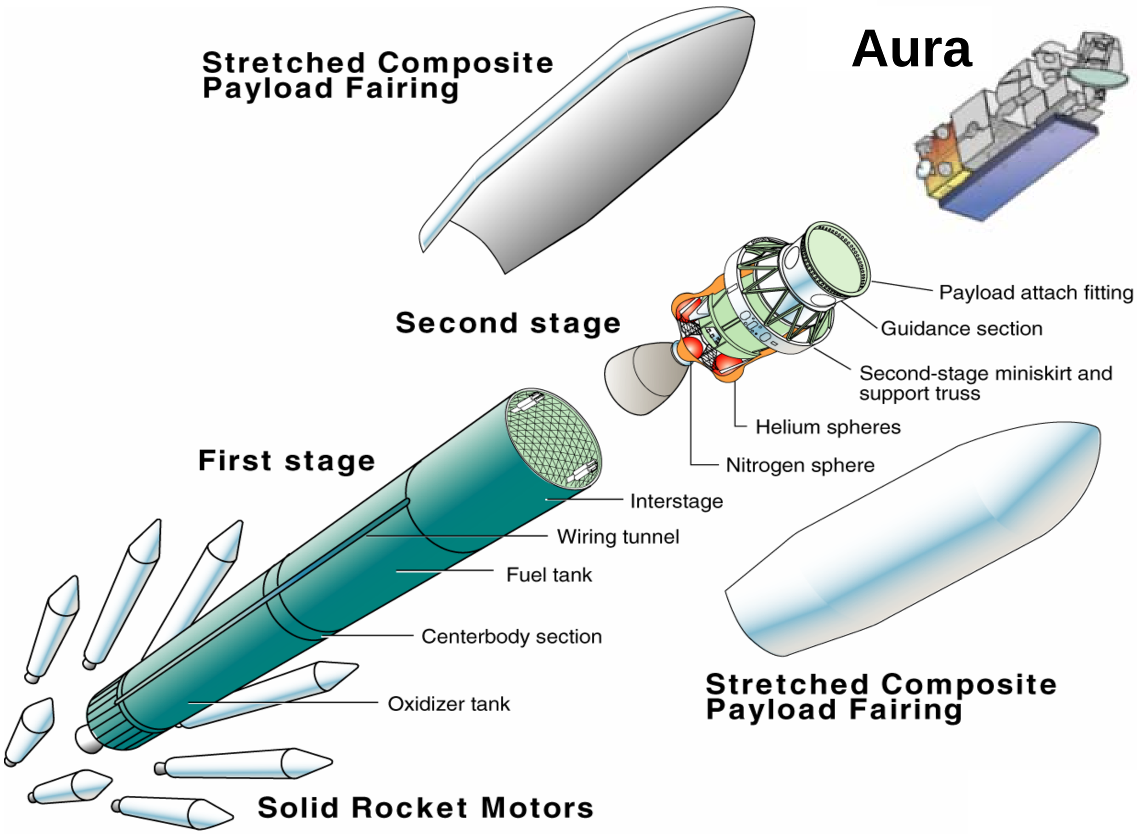
EOS Aura Satellite

Mission Profile

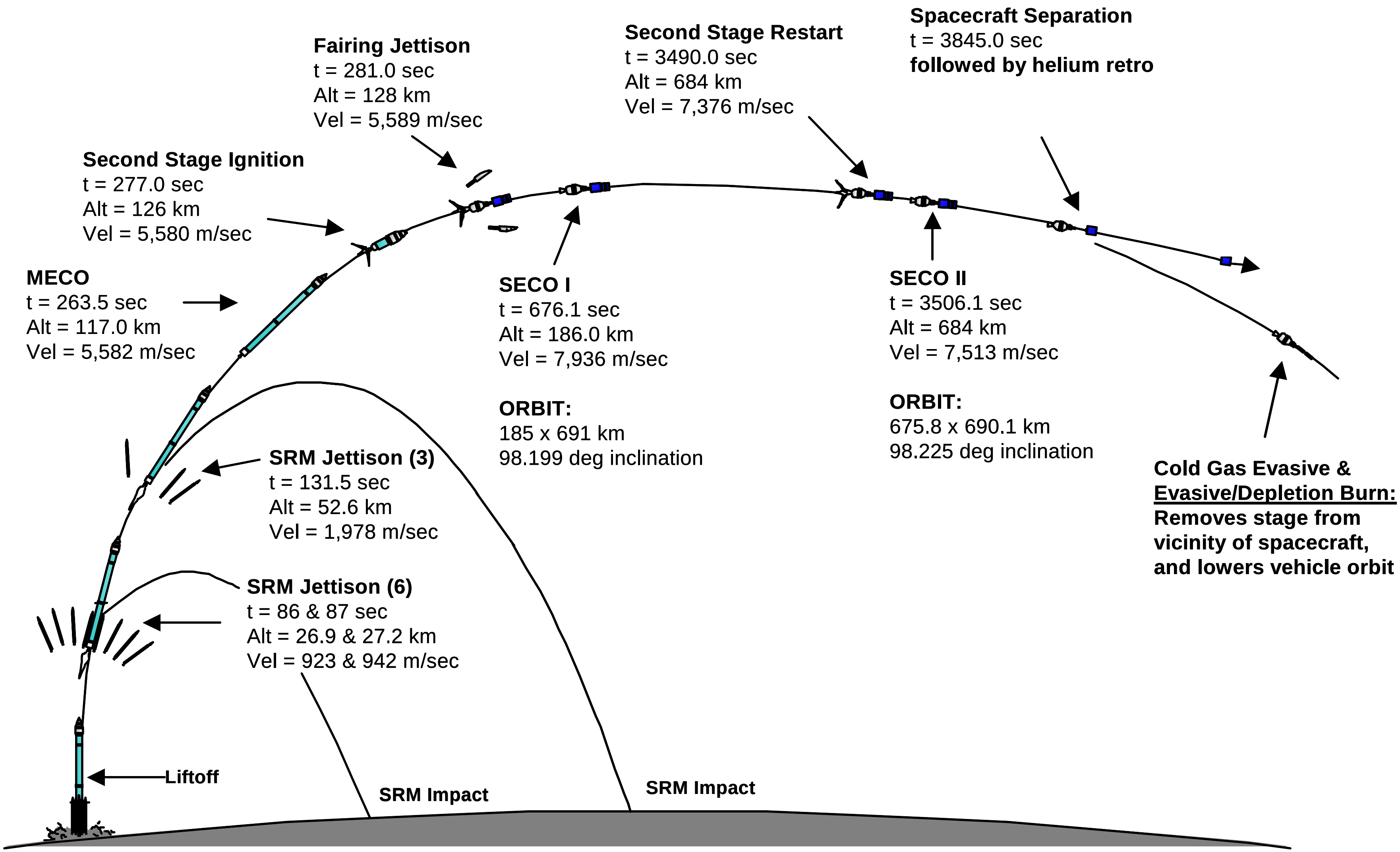
- Delta II 7920-10L launch from SLC-2W, Western Range, Vandenberg Air Force Base (VAFB) on June 19, 2004
- Launch window is 10:01:50 to 10:04:50 GMT, 6:01:50 to 6:04:50 GSFC time or 3:01:50 to 3:04:50 VAFB time
- 705 km, 98.2 degree sun-synchronous, 1:45 pm +/- 15 minute nodal crossing, 98.8 minute ascending orbit
- 16 day repeat cycle on the World Reference System (WRS)
- 5 year design life (7.5 years for consumables)
- 24 hour autonomous survival capability

EOS Aura/Delta II Configuration 7920-10L

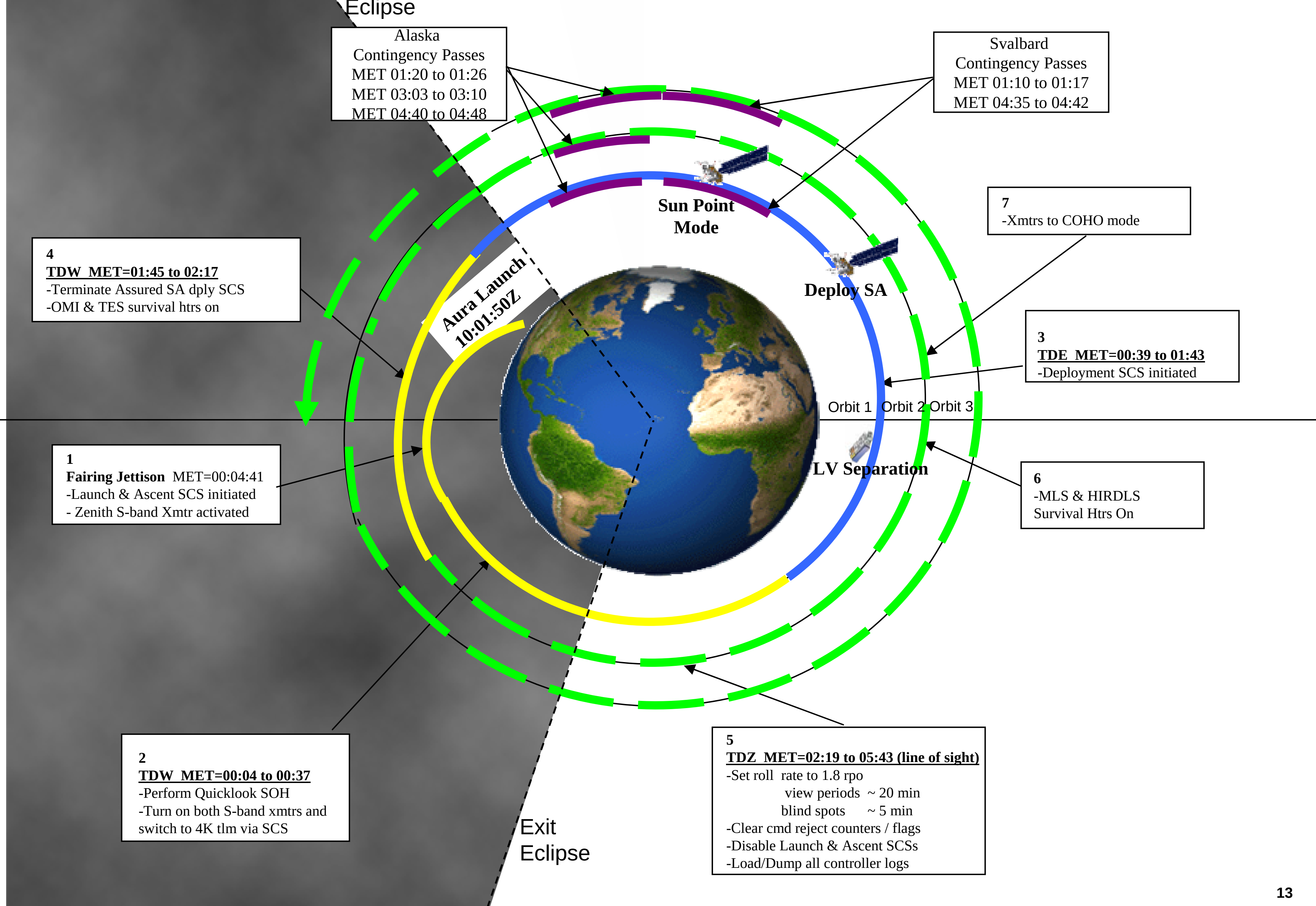
- Vehicle configuration: 7920-10L
- Launch site: SLC-2W at VAFB
- Launch date: 6/19/2004
- Unique mission requirements:
    - > 99.7% PCS
    - 6306 PAF with secondary latches
    - Retro nozzles with 35 degree cant
    - BBQ roll during coast phase
    - Super clean (VC-6) fairing
    - T-0 dry nitrogen purge



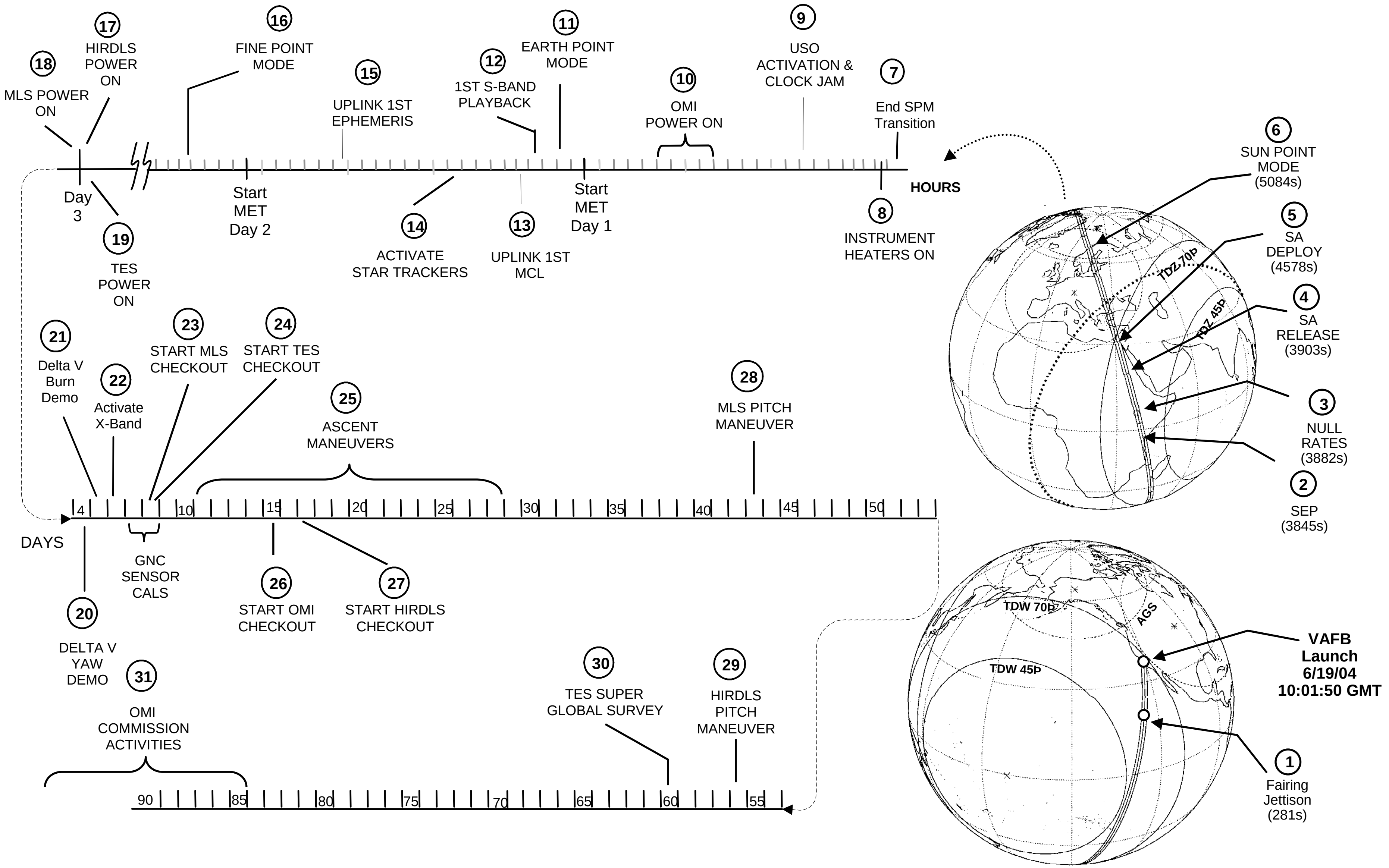
Flight Profile



Aura Launch Timeline



Launch, Activation and Checkout Critical Events



MET = Mission Elapsed Time

Orbital Debris/Safe Ocean Disposal

- **Aura is non-compliant with two Orbital Debris Assessment (ODA) guidelines**
  - Quantitative analysis required to show acceptable probability of explosion during normal operations; we only performed a qualitative assessment.
  - Aura's inability, by design, to vent residual nitrogen pressurant in propulsion system is non-compliant with requirement to minimize stored energy to reduce the probability of orbital debris generation after end-of-mission.
- **NASA HQ Code Q plans to provide to Code Y, by 5/7/04, a letter stating that these non-compliances pose minimal risk and recommending Aura be launched as-is.**
- **End of life disposal plan will be generated during nominal operations phase of Aura's mission.**
  - Decision to start de-orbit process based on remaining fuel or loss of critical redundancy.
  - Various options for final altitude, burning remaining fuel, etc will be analyzed.
  - Preliminary analysis indicates that 16 kg of 231 kg load is required to lower altitude sufficiently to reenter within 25 year guideline.

Satellite Readiness

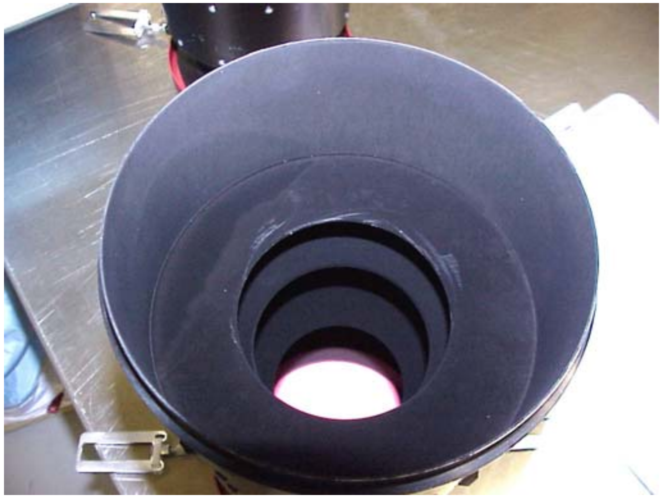
EOS Aura Satellite

EOS Aura Status

- Pre-Ship Review (PSR) held March 2-4, 2004 at NGST
- Satellite shipped to the launch site on April 1, 2004
- Satellite post-ship Comprehensive Performance Test (CPT) completed on April 20, 2004
- Completed final EOC-to-Satellite testing on April 25, 2004
- Satellite will be fueled on May 14, 2004
  - Potential liens discussed on following pages
- Satellite-to-Launch Vehicle mating scheduled for May 28, 2004
- Launch Readiness Review (LRR) scheduled for June 17, 2004
- Expect to launch June 19, 2004

Open Issue - Star Tracker Sun Shade

- **Problem: The second stage baffle of one shade has been scratched and the knife edge may be damaged.**
- **Solution: Determine if the baffle can be repaired. If so, strip the Martin Black coating and re-coat. If not, replace baffle. Continue investigating cause. Ensure I&T personnel trained in proper handling of shade.**
- **Status: When this happened is not known. Training complete. Shade returned to Ball, where scratched baffle has been removed and is being stripped.**
  - Inspect for re-use on 5/3.
  - If good, re-coating should take ~1 week.
  - In parallel, replacement baffle being made, in case needed. Ready for coating ~5/7.
  - Shade reassembly complete 5/13 (reworked baffle) or 5/20 (new baffle).
  - Reacceptance test complete 5/17 or 5/27.
  - Flight installation complete 5/24 (in Astrotech) or 6/7 (on pad).
- **Assessment: We have two viable paths that should not impact launch readiness. <u>Not a lien against fueling</u>.**



Open Issue - Battery Charging

- **Problem: Battery Capacity measurements at spacecraft level 6 to 8 amp-hrs (Ah) below "name plate" capacity of 160 Ah.**
  - **Battery health and capacity do not appear to be compromised.**
    - **Battery-level testing in January after removal from cold storage was in-family with all previous tests.**
    - **Cell voltage characteristics and cell-to-cell variations throughout charges/discharges all nominal. No sign of degradation over course of Spacecraft-level tests.**
  - **Battery cooling inefficiencies during charging suspected, limits charge applied.**
    - **Potentially associated with s/c orientation during charging. Aura has been horizontal, which gives no convective path for heat from cells; Aqua was vertical, which gave good path for heat rejection.**
      - **Clear increase in temperature rate-of-change during charging as compared to Aqua.**
      - **Application of air cooling to Battery compartment shown to reduce temperature rate-of-change during a top-off.**
    - **Could also be a change in efficacy of the test cooling loop, some of which is internal to s/c.**

Open Issue - Battery Charging (continued)

- **Solution: Confirm problem is cooling related and not capacity loss by performing another charge/discharge test, but with cooling air into battery cavity and with the spacecraft vertical.**
- **Status: Charge capacity test started on 5/3; results expected 5/4.**
  - **Was planned to start 4/29, but was delayed to a GSE cable problem.**
  - **Will follow with dry-run of pad charging process (accommodating pad constraints/limitations).**
- **Assessment: We are confident that the battery is healthy. If there is a capacity fading problem, we will need to assess the operational implications to determine what level of capacity loss would be unacceptable, as well as pursue the cause of the capacity loss.**
  - **<u>Demonstrating acceptable capacity is a lien against fueling</u>.**

Open Discrepancy Reports (DRs)

- **We have one outstanding significant DR**
  - Scratches on Star Tracker Sun Shade (discussed earlier).
- **13 DRs with cause unknown (Ghosts) have a disposition with no major mission impact.**
  - None have occurred since Observatory Pre-Ship Review, where all were discussed thoroughly.
  - Details follow.

Cause Unknown or Ghost Discrepancy Reports (1 of 5)

DR#	EVENT	DATE	RISK MITIGATION / WORK AROUND
DR8806	CTC-B Flight Software halted unexpectedly during first week of spacecraft C&DH integration. Software was subsequently reloaded with no further problems on CTC-B. Possibly due to controller susceptibility to noise introduced by Break out boxes on test line. Test port and equipment not used since initial integration.	7/22/02	Fault management will automatically reload CTC-B from EEPROM if CTC-B halt occurs. Should halt occur on CTC-A, fault management would automatically swap to CTC-B. Believe that this error was caused by a B.O.B. It has not occurred since the B.O.B. was removed.
RR27350	GNCC Flight Software halted unexpectedly during first week of spacecraft C&DH integration. Software was subsequently reloaded with no further problems on GNCC. Possibly due to controller susceptibility to noise introduced by Break out boxes on test line. Test port and equipment not used since initial integration.	7/16/02	Fault management will swap to GNCC-B if this were to occur on-orbit. Believe that this error was caused by a B.O.B. It has not occurred since the B.O.B. was removed.
RR22921	During CPT2's stand alone Communication Subsystem testing, the measurement of the return link frequency on one test of the frequency was 44 Hz (.000044 MHz) lower than the nominal 2287.5 MHz. Repeats of the test at the time did not show this discrepancy. This was a single occurrence. It has not reoccurred in any of the many re-runs of this test since. Telemetry indications point away from the spacecraft hardware, the most likely root cause is a one time "glitch" in the test equipment frequency counter.	5/16/03	This has not occurred since the original event during CPT #2. Should a momentary in frequency of this magnitude occur on-orbit, the frequency discrepancy would have no effect on the viability of the return link.
DR14881	HIRDLS Gyroscope motor 1 failed to start multiple times. Most probable cause is the gyro was commanded to start before warm-up.	12/24/02	Mitigation is to delay 2 minutes between Gyro Start commands among the 4 gyros. Also minimum turn-on temperature was added as an operational constraint. Mitigation techniques implemented and successfully demonstrated on ground without reoccurrence.

Cause Unknown or Ghost Discrepancy Reports
(2 of 5)

DR#	EVENT	DATE	RISK MITIGATION / WORK AROUND
DR24481	HIRDLS CMU Failure. Displacer counterbalancer failed during time period of first observatory dynamics test. Most probable cause is shifted magnet in motor.	3/1/03	NASA Headquarters decided to use-as-is. Cooler monitoring procedures implemented. Gradual cooler start-up procedure created and tested. Many Independent Reviews have been held on this failure.
DR16653	HIRDLS Calibration Heaters experienced erratic behavior that manifested as IFC telemetry jumps on the A-side only. Occurred during instrument level testing, Oxford calibration testing, and Spacecraft level I&T. Most probable cause is an intermittent part or manufacturing variance.	7/15/02	Mitigation action is to utilize atmospheric retrieval. In worst case, when IFC-A & B-Side fail, use atmospheric temperature retrieval. (Addressed in HIRDLS Delta-PSR RFA#5 and Aura PER RFA#16.)
PFRZ81068 DR16674	TES Interferometer Control System (ICS) Activation placed TES into SAFE mode. When ICS commanded to its present position during activation, internal fault protection puts TES into SAFE mode. There were two occurrences: CPT1 with Engineering Model and regression testing with the Flight Instrument. Unable to recreate with subsequent iterations (15-20 times) and never occurred during the unlatch sequence within the ATS. Most likely cause is a software/ICS encoder interaction that we do not fully understand.	6/24/03	The following mitigations were implemented for ground testing: velocity fault response disabled during activation but monitor remains enabled; changed ATS to check ICS encoder value & skip set up command if it is already at that position, then proceed with short scan; fault response re-enabled after short scan & before exiting ATS. The on-orbit contingency plan is very similar to that for ground testing and is as follows: during ICS activation, ATS will not execute setup scan-short command if encoder is already at that position; and ICS velocity fault response will not be enabled until after the first short scan.

Cause Unknown or Ghost Discrepancy Reports
(3 of 5)

DR#	EVENT	DATE	RISK MITIGATION / WORK AROUND
DR29087	TES Focal Plane B (FPCB) relay (K2) would not change state to open during Observatory-level Thermal/ Vacuum (Hot cycle test). The failure mechanism was only present during the reset of K2 which is executed during the power down of the Focal Plane Subsystem. The IEM assembly was purposely driven to exceed worst-case science Hot predictions by 10 degrees (per requirement 2.6.2.4 of GEVS, Rev A.)	10/16/03	This should not occur in flight for two reasons: (1) the anomaly occurred at proto-flight temp, which is 10C higher than worst-case orbital predictions, and (2) it only occurs when powering down the focal plane, which is not a planned event. Should it occur in flight, we have updated/tested macros operate both primary & redundant relays simultaneously to ensure shutdown of the mechanical cooler to preclude damage. If necessary, power cycling the Instrument Electronics Module (IEM) resets the condition if necessary.
DR35400	TES observed signal chain oscillation at 175Hz in a few pixels on two detectors in Aura thermal/vacuum test. Possible causes studied was a drift of beamsplitter in cell when cold or from a mechanical vibration outside of TES.	2/27/04	In zero gravity on-orbit, no drift of the beamsplitter is expected. If necessary, to avoid vignetting, TES will optimize performance by regulating the temperature of the optical bench as planned and discussed following Instrument-level System Test-5. In the worst case if the problem recurs without successful remediation on-orbit the TES science team will ignore the affected pixels with maximum signal to noise reduction of 6.5%. The lowest two pixels in 1A and 1B in limb views only see the ground or clouds; all the science information is in the other pixels. This minimally changes the averaging in the nadir from 16 to 14 pixels.

Cause Unknown or Ghost Discrepancy Reports
(4 of 5)

DR#	EVENT	DATE	RISK MITIGATION / WORK AROUND
PFRZ80246 DR18336	MLS first power on after integrating the ASE, did not turn on the ASE when commanded. This happened on both A and B sides. Most probable cause is an error that caused the C&DH to think the ASE RIU was already on, so it did not formulate an on command. If the RIU state table initially book kept the ASE status as on, the first acquisition table upload would not be successful in turning on the ASE – no change of state required. Subsequent tables would be successful because the RIU state is updated at the end of the initial acquisition. Since the event occurred on both A and B sides, it appears to be a software feature associated with the first power on after rework. There has never been a subsequent power on anomaly for the ASE.	3/15/03	If the ASE does not turn on when commanded on orbit, then the power on command will be resent.
PFRZ82393 DR29673	MLS TSE turned off during Aura Thermal/Vacuum test on the hot plateau. Error code indicated BEI electronics sensed a low when a high was expected at the end of a character. Most probable cause is a timing error in RS-232 interface between the RIU and BEI electronics such that the receiver missed a bit frame and was looking for a stop bit and saw a start bit for the next character. This interface is only accessible for testing at the subsystem level.	10/1/03	A timing error may be correctible with an update to the RIU HEX code to increase the transaction time. Implementation of this change was not performed because the event is so rare that even a long test without occurrence is not proof that the code change was effective. The RIU HEX change can be implemented on-orbit if frequency increases in the future.

Cause Unknown or Ghost Discrepancy Reports
(5 of 5)

DR#	EVENT	DATE	RISK MITIGATION / WORK AROUND
PFRZ81142 DR25865	During MLS FSW testing, the Antenna Launch Latch (ALL) execute command operated for 150 msec. Should have been 30 sec. Error messages indicated that the RIUL intended to precondition the GMEB RIU did not upload properly. The short pulse was probably due to a high DN value in the buffer, a behavior noted in previous ALL/FSW testing. The high DN was interpreted by FM as an over temp condition on the ALL and turned off the latch heater in the next minor frame. The cause of the RIUL not loading properly was not determined, but subsequent system response was correct.	6/30/03	Procedure changed to clear buffer, place in known configuration before sending enable command. On-orbit plan is to re-send the command. Also, there is redundancy.
PFRZ83063 DR35569	MLS Receiver #3 (R3) Phase Lock Loop changed during high temperature testing in Aura Thermal/Vacuum, a decrease in IF power occurred.	10/8/03	Performance degradation found to be caused by high temperature exposure during T/V. On-orbit operating temperature has been reduced by increasing radiator area (removing MLI). MLS is in specification with 7db of margin and the lowered operation temperature is expected to reduce or eliminate the rate of degradation. An available on-orbit contingency response is to operate R3 with phase lock disabled with ground software modification. This would likely degrade performance, but not beyond useful limits, of the constituents measured by R3: O3 (band 7) and HNO3 (bands 8 and 9).

Major Aura Reviews - Completed

Common Bus System Concept Audit (SCA)	August 22, 1996
Common Bus Requirements Review (BRR)	December 3, 1996
Common Bus Preliminary Design Review (PDR)	April 29, 1997
Common Bus Critical Design Review (CDR)	June 16, 1998
Common Bus Flight Software CDR (FSW CDR)	August 10, 1998
System Requirements Review (SRR)	July 20, 1999
Spacecraft ΔPDR	November 16, 1999
Spacecraft ΔCDR	September 12, 2000
Flight Software Acceptance Review (FSW AR)	August 7, 2002
Mission Operations Review (MOR)	February 19, 2003
Aura Pre-Environmental Review (PER)	April 2, 2003
Phase III Safety Review	December 16, 2003
Flight Operations Review (FOR)	February 24, 2004
Pre-Ship Review (PSR)	March 4, 2004
Pre-Vehicle On-Stand Review (Pre-VOS)	April 22, 2004
KSC Launch Vehicle Readiness Review (LVRR)	May 3, 2004

Major Aura Reviews - Future

Mission Readiness Review (MRR)	May 4, 2004
Science Operations Readiness Review (SORR)	May 11, 2004
Code Y MRR Summary	May 21, 2004
Launch Site Readiness Review (LSRR)	June 1, 2004
Flight Readiness Review (FRR)	June 15, 2004
Mission Dress Rehearsal	June 16, 2004
Launch Readiness Review (LRR)	June 17, 2004

Open Issues from Major Reviews

Flight Operations Review (FOR)

- Responses have been submitted for all 14 Requests for Action (RFAs). All are closed.

Pre-Ship Review (PSR)

- Responses have been submitted for all 9 RFAs. 7 are closed. The following are in review:

RFA#	Subject
1	Instrument Performance/System Dynamic Interaction
4	MLS HBT Reliability (discussed on next page)

All other issues from remaining reviews are closed.

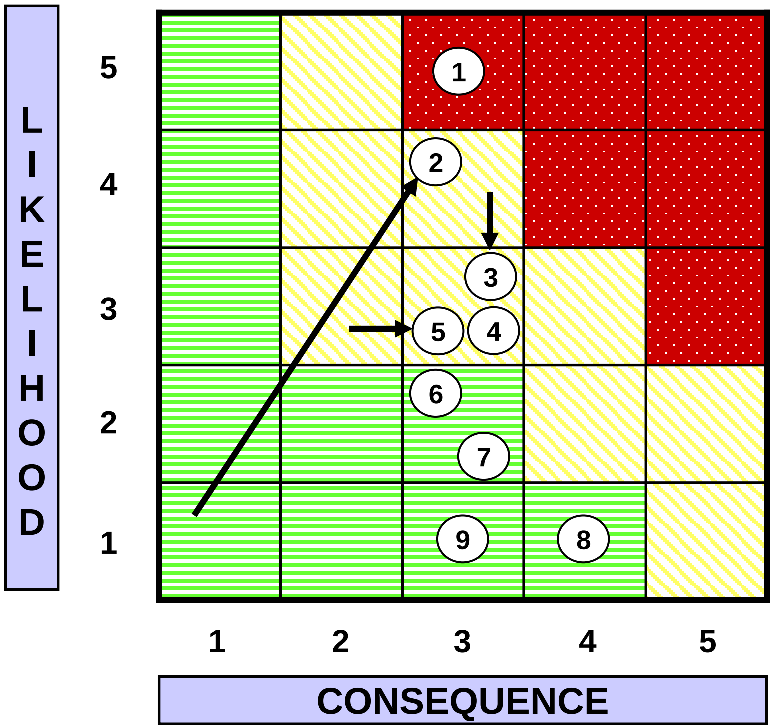
Open RFA - MLS HBTs

- **Problem: MLS contains 84 Heterostructure Bipolar Transistors (HBTs) that have less than five years estimated life, 18 in Phase-locked Oscillators (PLOs) and 66 in Intermediate Frequency Down Converters (IFDCs).**
  - **HBTs were manufactured by NGST as commercial parts, and have residual emitter thickness (RET) thinner than desired. RET degrades based on temperature and current density, and results in reduced current gain (beta) over time.**
  - **JPL identified numerous uncertainties, and both overly- and non-conservative factors in the lifetime estimates. They removed one of NGST's conservative factors, making their estimates slightly less conservative than NGST's, whose methodology has been independently reviewed by Aerospace and Lockheed Martin.**
  - **The lifetime estimates are based on life testing of four parts, and represent the point at which a reduction in gain to 2% could occur in 2% of HBTs. JPL analysis shows that the circuit still operates with 2% gain (JPL expects graceful degradation to 2% and as it degrades beyond that).**
  - **HBTs with suspect lifetimes are in the PLOs for some, but not all, science bands and in the IFDCs for every band.**
  - **Either MLS or other Aura instruments make redundant measurements for all 34 MLS measurements except HCl, HCN and HOCl; HCl is the only one that would be considered a significant loss.**

Open RFA - MLS HBTs (continued)

- **Solution: Either accept risk as-is or develop replacement plan (cursory assessment is >1 year due to significant disassembly of MLS, rework of subcontracted hardware, and necessary retest/calibration).**
  - **If risk is accepted, JPL will monitor science band performance; if degradation is observed, they can make operational changes (change gains and/or reduce duty cycles) to extend measurement life (e.g., for long-term HCl measurements, one day per week would provide the needed data).**
- **Status: Codes 300 and 500 are assessing whether or not they concur with JPL's lifetime estimates and concomitant risk ratings. They are also pursuing classified HBT data base, which covers a much larger population of parts.**
- **Assessment: JPL assessed this risk as Medium (L=3xC=3) for 5 years and Low (2x3) for Mission Success. Our risk rating is 4x3 and 2x3, respectively. Code 301 has just started looking at this, and has indicated this may be too low.**
  - **<u>Obtaining risk acceptance by GSFC leadership and Code Y is a lien against fueling.</u>**

Aura Residual Risks - Summary
Projected vs. Level 1 Requirements



Trend	Approach	Risk Title
1 ⇨	A	TES Translator Mechanism Lifetime
2 ⇧	Issue	MLS Commercial HBTs
3 ⇩	A	HIRDLS Cooler Lifetime
4 ⇨	M	MLS Mechanism Life Test
5 ⇧	A	MLS THz ADSP2100 Latch-up
6 ⇨	A	TES On-Orbit Alignment
7 ⬡	A	MLS ADG 411 Rad Tolerance
8 ⇨	M	OMI On-orbit Calibration
9 ⇨	A	TES EEPROM bit failure

Criticality	L x C Trend	Approach
H	⇩ Decreasing (Improving)	M - Mitigate
M	⇧ Increasing (Worsening)	W - Watch
L	⇨ Unchanged	A - Accept
	⬡ New Risk	R - Research

Aura Residual Risks

Rank & Trend	Risk Statement	Approach & Plan	Status
1 **Criticality** H **LXC=5X3=15**	**TES Translator Mechanism Lifetime –** **IF:** The flight translator mechanism displays the same behavior as the life test unit, **THEN:** Operational lifetime of flight unit should be expected to be ~2 years.	**Accept** – Premature failure of life test unit believed a design issue. Flight unit should meet mission success criteria (one year of operation). We may reduce TES' operations in order to minimize the interferometer's operation and extend its life. We will operate instrument as planned for first six months, then evaluate translator performance to determine whether to reduce operations. AETD Risk Caucus on July 10, 2003 reviewed issue and agreed that risk is high versus level 1 requirement and low versus Mission Success Criteria.	We don't expect to meet Level 1 lifetime requirement (five years). <u>Waiver request is into Aura configuration review for signature.</u> We do meet the reduced life time requirement (one year) per the Mission Success Criteria.

Aura Residual Risks

Rank & Trend	Risk Statement	Approach & Plan	Status
2 **Criticality** M **LXC=4x3=12**	**MLS Commercial Grade Heterostructure Bipolar Transistors (HBTs) –** **IF:** HBT parts fail before 5 years **THEN:** Some MLS science bands may be lost, the significance of which will be determined by which ones and how many.	**Mitigate –** Determine if the life estimates for the HBT parts were calculated using overly conservative parameters. (CLOSED) Determine which channels have redundancy either within MLS or on the Aura platform. (CLOSED) Obtain agreement with Codes 300 and 500 on likelihood of occurrence. If HBTs flown as-is, monitor on-orbit performance closely for indications of degrading performance, and implement operational changes (adjust gains and/or reduced duty cycles) to extend lifetime of affected measurements.	Based on a more thorough review of the applied currents and temperatures of each part, JPL's final report dramatically changed the lifetime predictions. The quantity of HBTs of most concern to us increased from ~10 to 84. JPL assesses this as Low risk (2x3) for meeting Mission Success Criteria and Medium risk (3x3) for meeting the full 5-year life. Top-level estimate for replacing HBTs is >1 year.

Aura Residual Risks

Rank & Trend	Risk Statement	Approach & Plan	Status
3 (down arrow) **Criticality** M **LXC=3X3=9**	**HIRDLS Cooler Lifetime –** **IF:** The counterbalancer failure occurs in one of the other cooler motors, or if the cryo-cooler life test uncovers design of fabrication flaws, **THEN:** Operational lifetime requirements of HIRDLS may not be achieved.	**Accept** – Intensive investigation and analysis has shown that the Cooler Mechanical Unit (CMU) counterbalancer mechanism has both an electrical short and mechanical blockage. Disabling the counterbalancer has allowed HIRDLS to perform as required. However, the root cause of these failures is unknown, and both failures modes are possible in the displacer (and maybe compressor). Because of the expected lengthy duration and unknowns associated with repairing the CMU, it will be used as-is, leaving HIRDLS an expensive, high-risk instrument. GSFC cryo-cooler should accumulate 45% life; will continue to monitor for any behavior not seen in flight unit.	<u>As discussed at April MSR, likelihood has been reduced to 3 (from 4) based on discussions at Aura Pre-Ship Review</u>. <u>A Memorandum for the Record documenting the “use as-is” decision made on 1/21/04 has been sent to Code Y, as requested. The responses to the action items from that same meeting have also been provided.</u>

Aura Residual Risks

Rank & Trend	Risk Statement	Approach & Plan	Status
4 **Criticality** M **LXC=3X3=9**	**MLS Mechanism Life Test –** **IF:** Life tests for critical mechanisms have not started, **THEN:** Operational lifetime may be reduced, or cost and schedule will be impacted to effect repairs.	**Mitigate –** Perform Life test of AAA and switching mechanism. Perform Ball Pass Analysis of AAA bearing set and ball screw. Ball-pass analysis of bearing set (i.e., not the ball screw) in AAA by GRC shows moderate probability of achieving 5 years of operation, and high probability for mission success.	AAA life test has completed ~16.2% of one life; by launch, ~25% of one life should be completed on the AAA. TSSM life test has completed 8.7% of one life; by launch, ~20% of one life will be completed.

Aura Residual Risks

Rank & Trend	Risk Statement	Approach & Plan	Status
5 **Criticality** M **LXC=3X3=9**	**MLS THz ADSP2100 Latch up –** **IF:** Destructive or "non-destructive" latch-up occurs, **THEN:** THz receiver (needed for OH measurement) may not operate for five years.	**Accept –** Crowbar circuit and software protection have been implemented to prevent catastrophic latch up, but latent damage could still occur that would affect performance or reduce life. P_s = 0.97 for one year, 0.85 for five years. Achieving Mission Success requires one year.	<u>While preparing response to PSR RFA#5, Aura Project Scientists have concluded that the impact to level 1 requirements of losing this measurement is higher than previously assessed, so consequence rating has been changed from 2 to 3.</u>

Aura Residual Risks

Rank & Trend	Risk Statement	Approach & Plan	Status
6 **Criticality** L **LXC=2X3=6**	**TES On-Orbit Alignment –** **IF:** TES can only withstand a limited number of thermal cycles before losing ability to achieve optical alignment needed to meet science performance, **THEN:** Performance degradation would occur over TES' life if unexpected/anomalous events cause excess thermal cycles.	**Accept –** JPL estimates that TES can withstand at least two additional on-orbit thermal cycles and still meet all level 1 requirements. After initial cool-down, no other thermal cycling is planned, and operational procedures have been implemented to minimize the likelihood of exceeding the estimated cycling limit. If any degradation in alignment occurs due to thermal cycling, it would lead to only gradual performance changes, not catastrophic and sudden degradation. Steering the beam splitter with small changes of interferometer temperature may mitigate some, if not all, changes in alignment. This assessment was reviewed via an AETD risk caucus.	

Aura Residual Risks

Rank & Trend	Risk Statement	Approach & Plan	Status
7 Criticality L LXC=2X3=6	**MLS ADG 411 Rad Tolerance –** **IF:** The ADG411 semiconductor switch fails prematurely due to total ionizing dose (TID) exposure, **THEN:** Performance of the THz module (measures OH) could be degraded.	**Accept –** JPL states that ADG411 is good to 4 krad TID (with 2x radiation design margin) vs. required 5 krad, but has not provided supporting documentation. Three ADG411s are used to change gain of the THz Gas Laser Local Oscillator (GLLO), and is rarely used. Should part failure occur, impact would depend on gain setting at that point and whether any subsequent gain changes were needed. One year of OH measurement needed for Mission Success.	

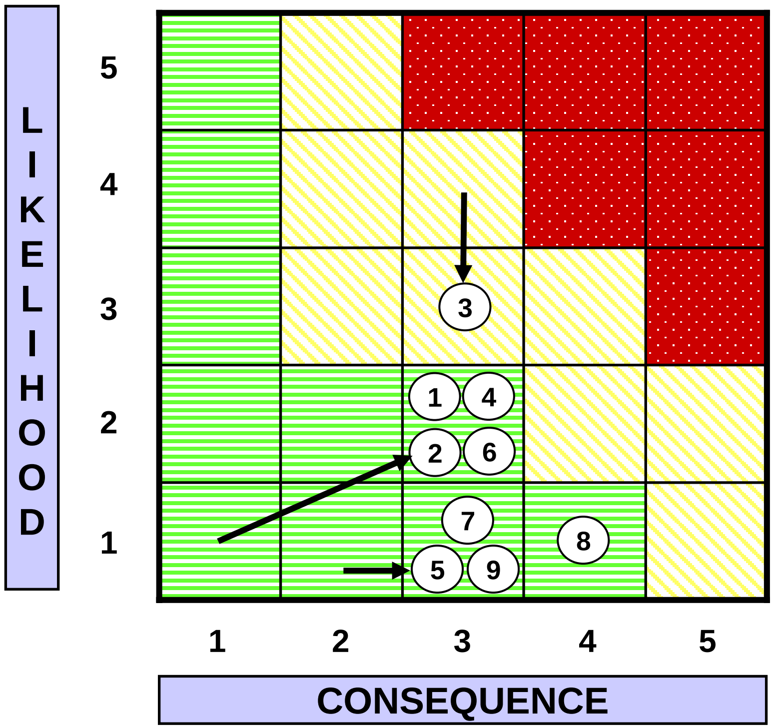
Aura Residual Risks

Rank & Trend	Risk Statement	Approach & Plan	Status
8 **Criticality** L **LXC=1x4=4**	**OMI On-Orbit Calibration** **IF:** Deficiencies in existing calibration data base cannot be resolved, **THEN:** On-orbit calibration will take longer than planned, or some OMI Data Products may not fully meet Level 1 requirements.	**Mitigate** – Repeat calibration analysis making use of previously excluded data (In-process). Assess what Level 1 science requirements would not be met given current understanding of calibration data and what can be achieved post-launch <u>(CLOSED per PSR RFA acceptance by IIRT).</u> NIVR to obtain additional funding from Dutch Ministries in order to perform increased post-launch instrument calibration/characterization <u>(out-year operations funds that are being used to cover near-term calibration efforts need to be replenished)</u>. NIVR to request from HQ support from GSFC to help in this effort <u>(CLOSED).</u>	Code 910 has high confidence in successfully completing the OMI calibration on-orbit, as was performed successfully on other missions (TOMS, SSBUV, GOME). Data product release has been prioritized, with TOMS-like data projected for 9-12 months after launch. Data loss is not a concern, as all data will be captured and can be reprocessed. <u>NIVR and Code 910 presented the approach for on-orbit calibration, including GSFC support, to Code Y/AA on 4/15/04. Code Y accepted the plan and has committed to fund the effort.</u>

Aura Residual Risks

Rank & Trend	Risk Statement	Approach & Plan	Status
9 **Criticality** L **LXC=1X3=3**	**TES EEPROM bit failure –** **IF:** The first 36 bytes of EEPROM, or the FSW copy selected in EEPROM, becomes corrupted, and we do not correct it before TES is subsequently turned off (which would require another anomalous event), **THEN:** TES could not be rebooted.	**Accept –** All changes have been implemented and tested that could be done without fundamental restructuring of Flight Software or making intrusive hardware changes (which would have introduced more risk than that being mitigated). AETD agrees that no further changes are needed. Testing by JPL showed that with FSW write protection enabled (which is in FSW v20), the risk associated with TES' power switching implementation is acceptable. BAe (Rad 6000 vendor), Maxwell (chip vendor) and AETD agree.	

Aura Residual Risks - Summary
Projected vs. Mission Success Criteria



Trend	Approach	Risk Title
1	A	TES Translator Mechanism Lifetime
2	Issue	MLS Commercial HBTs
3	A	HIRDLS Cooler Lifetime
4	M	MLS Mechanism Life Test
5	A	MLS THz ADSP2100 Latch-up
6	A	TES On-Orbit Alignment
7	A	MLS ADG 411 Rad Tolerance
8	M	OMI On-orbit Calibration
9	A	TES EEPROM bit failure

Criticality	L x C Trend	Approach
H	Decreasing (Improving)	M - Mitigate
M	Increasing (Worsening)	W - Watch
L	Unchanged	A - Accept
	New Risk	R - Research

Flight Software IV&V

Marcus Fisher

IV&V Approach, Goals and Objectives

- **In April 2001, the IV&V Facility was directed to perform IV&V on the Aura Project**
  - The Aura Project was in the testing phase of its life cycle
- **A Criticality Analysis and Risk Assessment (CARA) was performed in order to scope the IV&V Activities**
  - The objective is to optimize (or tailor) the approach to focus on the most critical areas to best utilize resources
  - The Critical Functions List (CFL), created as a result of the CARA, defines those software functions that the IV&V activities shall focus their work on
- **The goal of the Aura IV&V effort was to verify that the Aura test program is adequately defined and verifies critical functions of the Aura spacecraft and instrument software.**
- **Objectives:**
  - Confirm that software test planning was adequately defined to verify that the software was properly tested and met specified performance
  - Confirm that software requirements have been allocated to tests
  - Confirm that requirements associated with critical functions were fully addressed by the assigned test(s), and upon successful completion, the requirements could be considered fully verified
  - Confirm that test results were as expected for the most critical functions
  - Confirm that testing demonstrated that the software performs reliably under realistic and stressful mission scenarios

IV&V Results

- **Verified test plans were accurate and complete.**
- **Verified all software requirements were allocated to one or more test cases and that the selected qualification method - (Inspection, Demonstration, Test, Analysis) was appropriate.**
- **Verified S/C FSW, MLS, IAM, HIRDLS, and TES test procedures were complete and adequately addressed the software requirements associated with critical functions.**
- **Verified MLS and TES software hazard and safety conditions were identified and the software requirements and testing for such were adequately documented.**
  - A formal software safety analysis was not needed for S/C, IAM and HIRDLS based on review of their respective testing approaches, processes, and results.
- **Verified that Comprehensive Performance Test (CPT) procedures, including automated test scripts, exercised key spacecraft and instrument functions, and assessed the number of spacecraft and instrument commands that were exercised by the test procedures and test scripts.**
- **Static analysis of the MLS FSW code did not reveal any issues for the Project defined mission scenarios.**
- **Verified FSW changes have been adequately regression tested.**

IV&V Conclusion

- **The Aura test program is adequately defined and verifies critical functions of the Aura spacecraft and instrument software**

- **We concur with proceeding to launch**

Backup Charts

MLS HBT Life Estimates

Application	Current (mA)	Junction Temperature C	NGST Predicted Years to 2% beta	JPL Predicted Years (BF5) to 2% beta	JPL Predicted Years (ASR) to 2% beta	JPL Predicted Years (LTF) to 2% beta
MITEQ PLO -12 SIF4						
CRO Level 2 U2D	46	149.41	1.55	**2.41**	3.41	8.42
MITEQ PLO -13 SIF1						
X4 Mult Level 3 A2	46.1	172.53	1.04	**1.62**	2.288	5.65
X4 Mult Level 3 A1	46.1	172.53	1.04	**1.62**	2.288	5.65
MITEQ PLO -16 SIF4						
CRO Level 2 U2D	46	149.41	1.55	**2.41**	3.41	8.42
MITEQ PLO -20 SIF5						
X6 Mult Level 3 A2	49.1	178.43	0.88	**1.37**	1.936	4.78
X6 Mult Level 3 A1	49.1	178.43	0.88	**1.37**	1.936	4.78
MITEQ PLO -25 R1A 1st LO						
X4 Mult Level 3 A2	53.2	191.32	0.60	**0.93**	1.32	3.26
X4 Mult Level 3 A1	53.2	191.32	0.60	**0.93**	1.32	3.26
MITEQ IFDC (SIF)						
SIF1A						
A1	42 / 47.7	130.57 / 155.79	2.56/1.27	**3.97/1.97**	5.6/2.8	13.9/6.9
A2	42 / 47.7	130.57 / 155.79	2.56/1.27	**3.97/1.97**	5.6/2.8	13.9/6.9
A3	42 / 47.7	130.57 / 155.79	2.56/1.27	**3.97/1.97**	5.6/2.8	13.9/6.9

MLS HBT Science Impacts

Measurement	Primary MLS Bands	DACS	Other Bands	Miteq Part Nos. (with worst-case HBTs)	JPL Predicted Years (BF=5)	Assembly affected	Comments	Is MLS the Primary Aura Meas?	Measured by TES or HIRDLS
Press/Temp GHz (Note 1)	**1** 8 **32w**	**22** 26r	21r 34wr	-25	0.93yr	R1A	A & B side Redundancy		
	1			-13	1.62yr	SIF1A	A & B side Redundancy		
	21			-13	1.62yr	SIF1b	A & B side Redundancy		
H2O	2	23						Primary	YES
N2O (Note 2)	3 **12**			-16	2.41yr	SIF4			YES
HNO3	4 8 9								YES
ClO	5 10							Primary	
O3	6 7 14 33w	24							YES
CO	9	25							YES
BrO (Note 3)	**11** 31			-12	2.41yr	SIF4			
HCl	13							Primary	
HCN	27								
HO2	28 30								
HOCL	29								
Press/Temp THz	17 20								
OH (Note 4)	15 **16** 18 **19**			-20	1.37yr	SIF5		Primary	

jf 4/9/2004

r=redundant
w=wide

RED = Bands impacted by HBTs with a predicted beta reduction to less than 2% in less than 2.5 years except IFDCs.
90% confidence, 98% reliability, beta factor of 5 used for this chart.

Notes:
1. Receivers R1A/SIF1A and R1B/SIF1B provide full redundancy for Press/Temp GHz measurements.
2. Band 3 provides good redundancy for band 12 in measuring N2O.
3. Band 31 provides lower quality data than band 11 for measuring BrO and is a marginal backup. However, this PLO's time to 2% beta is 2.41 years, which is close to the 2.5 year criteria.
4. Bands 15 and 18 provide good redundancy for bands 16 and 19 in measuring OH.
5. Bands 1 to 21 are 25 channel filterbanks
6. Bands 22 to 26 are DACS (for mesospheric measurements)
7. Bands 27 to 31 are 11 channel filterbanks
8. Bands 32 to 34 are wide-band filters

MLS HBT Parts with Predicted Life Between 2.5 and 5 years

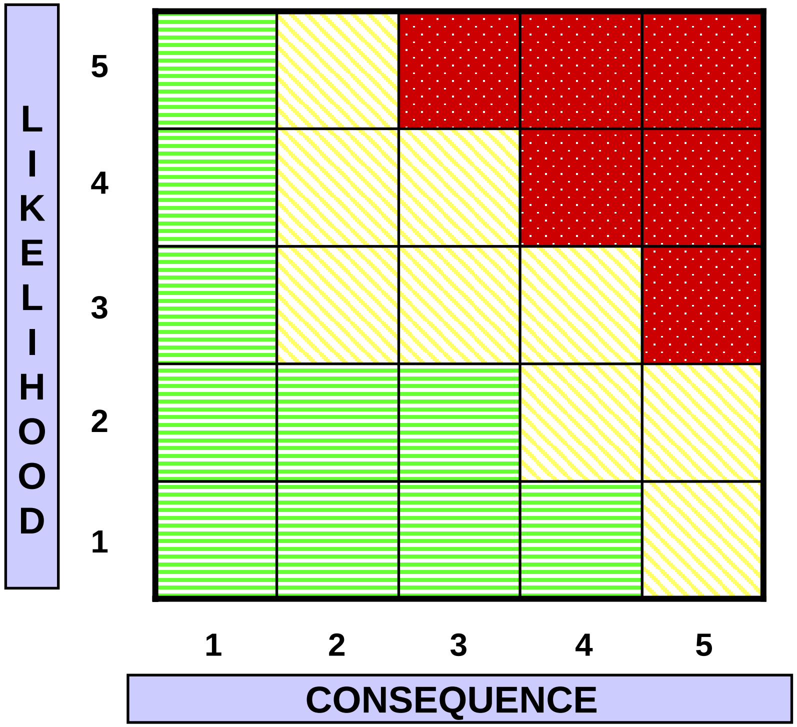
PLO	Assembly	Band	Measurement	Also Feeds	Measurement	Comments	yrs, BF=5
-7	SIF3	8	PT, [HNO3]			[ ] = secondary measurement	3.16
-17	SIF2	4	HNO3			3 devices	2.78, 2.78, 3.16
-18	SIF2	6	O3	27	HCN		3.16
-19	SIF2	5	ClO				3.16
-21	SIF4	13	HCl				3.16
-22	SIF4	14	O3				3.16
-24	SIF5	17/20	PT (THz)			One PLO feeds both Bands	2.58

HBT History/Background

- NGST issued amendment to GIDEP Advisory #G4-P-02-01A in June 2003 that stated their HBT parts should not be used in space or high reliability applications.
- We reported at the July 2003 MSR that JPL had reviewed the HBT parts in MLS and concluded they had acceptable lifetimes. The Aura spacecraft nor other instruments use HBTs.
- In winter 2003, we heard from NGST that JPL was re-looking at the lifetime predictions.
- In March 2004, we presented at both the S/C Pre-Ship Review and MSR that JPL believed only 10 parts had lifetime issues based on more accurate current predictions.
- At the April Aura MSR, we presented that JPL thought only 2 bands were at risk due to lifetime issues, and that the analysis was conservative.
- In mid/late April, we received a report from JPL stating that a large number of devices had lifetimes that didn't meet level 1 requirements or MSC.
  - JPL's final report radically changed the life time predictions of the HBT parts, based on a more thorough review of the applied currents and temperatures of each part.

HBT History/Background (cont'd)

- **Assessed Low risk for meeting Aura Mission Success Criteria and Medium risk for all MLS measurements meeting the full 5-year life**
- **Risk is that statistically a few of the 34 MLS measurements *may* be lost towards end of mission.**
- **The medium risk assessment is based on a lack of information on degradation of the parts beyond the 'life' estimate (at which level there is no impact on device performance)**
- **The effect, if any is a graceful degradation through the loss of some measurements, rather than catastrophic loss of the MLS Instrument**
- **MLS is redundant or we have redundancy within one or more of the other Aura Instruments for all 34 measurements except for 3: HCl, HCN and HOCl. HCN and HOCl measurements are not considered crucial**
  - **The HCl measurement is crucial for monitoring total stratospheric chlorine, and determining if international regulations (Montreal Protocol) are working**
  - **If performance degradation attributable to this issue is seen, we will reduce the duty cycle of this measurement to extend the life for long term HCl measurements – one day per week would provide the needed data.**



EOS Aura Risk Definitions

Likelihood Level	Likelihood of Risk Occurrence
1	Extremely Remote
2	Unlikely
3	Possible
4	Likely
5	Highly Likely

LEGEND

- High- Implement new process(es) or change baseline plan
- Medium- Aggressively manage-- Consider alternative process
- Low- Monitor

CONSEQUENCE

Level	Technical Impact	Schedule Impact	Cost Impact (To Go)	Science/Mission Impact
1	**Minimal or none**	**Minimal or none**	**<$100,000**	**Minimal or none**
2	**Some margin reduction**	**Additional resources required to meet need date**	**$100,000 to <$300,000**	**Science objectives impacted or degraded, but science still valid**
3	**Significant margin reduction**	**Schedule slip affecting critical path but not Launch**	**$300,000 to <$500,000**	**A few science objectives not met but mission science still valid overall**
4	**No margin remaining**	**Major slip in key milestone**	**$500,000 to <$1,000,000**	**Some science objectives not met**
5	**Below requirement**	**Schedule slip affects Launch date**	**>1,000,000**	**Most or all mission science objectives not met**

Aura Level 1 Verification Status as of 4/30/04 (1of 2)

Aura Project Plan Para. #	Section Title	Number of Requirements	Pre-launch	On-orbit Activation & Check-out*	Post-Handover/Normal Ops*
			Actual	Plan	Plan
4.1	Mission Success Criteria	6	0	1+ ##	4+ ##
4.2	Aura Project Requirements	N/A	N/A	N/A	N/A
4.2.1	Classification Criteria	1	1	0	0
4.2.2	Consultative Committee on Space Data Systems Standards	1	1	0	0
4.2.3	Data Formats	1	1	0	0
4.2.4	Data Transmission	1	1	#	0
4.2.5	Communications	4	4	#	0
4.2.6	System Testing	1	1	#	0
4.2.7	Technology Transfer	1	1	0	0
4.2.8	Orbital Debris	1	1	0	0
4.2.9	EOS Data Policy	1	1	0	0
4.2.10	Science Investigation	1	1	0	0
4.2.11	Aura Mission	1	1**	#	0
4.2.12	Spacecraft Launch	1	1	0	0
4.2.13	Spacecraft Orbit	1	1	#	0
4.2.14	Science Data Intercomparison	1	&	0	1
4.2.15	Spacecraft Health and Safety	1	1	0	0
4.2.16	Investigator Responsibilities	1	1	0	0
Sub-totals		25	18 of 18	1+	5+

(*) 4/21/04 Draft "Aura On-orbit Mission Verification Plan" out for review
(##) Verification of "capture, process and calibrate" is partially achievable before full verification and validation during "Post-Handover/Normal Ops Phase".
(#) Confirm pre-launch verification and no degradation due to launch and on-orbit environment.
(**) CCR 424-12-26-039 "Request to Waive TES 5-Year Life Requirement" (due to Translator Life Test) under review.
(&) Verification of HIRDLS, MLS and TES pre-launch calibration substantiated. OMI calibration will be completed on-orbit.

Aura Level 1 Verification Status as of 04/30/04 (2 of 2)

Aura Project Plan Para. #	Section Title	Number of Requirements	Pre-launch	On-orbit Activation & Check-out*	Post-Handover/ Normal Ops*
			Actual	Plan	Plan
4.2.17	HIRDLS	*	*	*	*
4.2.17.1	Description	*	*	*	*
4.2.17.2	[HIRDLS Science] Requirements	15	~	0	15
4.2.18	MLS	*	*	*	*
4.2.18.1	Description	*	*	*	*
4.2.18.2	[MLS Science] Requirements	19	~	0	19
4.2.19	TES	*	*	*	*
4.2.19.1	Description	*	*	*	*
4.2.19.2	[TES Science] Requirements	10	~	0	10
4.2.20	OMI	*	*	*	*
4.2.20.1	Description	*	*	*	*
4.2.20.2	[OMI Science] Requirements	14	~	0	14
4.3	Observatory System I&T	2	2	0	0
Sub-totals		60	2 of 2	0	58
Previous Slide Sub-totals		25	18 of 18	1+	5+
Grand Totals		85	20 of 20	1+	63+

(*) 4/21/04 Draft "Aura On-orbit Mission Verification Plan" out for review

(~) Pre-launch, the ESDIS science system testing demonstrated the production capability for the instrument Standard Data Product requirements defined in the Aura Project Plan (Table 4-1). The Principal Investigator (PI) validation of these products using calibration and trending data will start after the instrument activation and checkout has completed.

Mission Success Criteria

1. **Achieve orbit and complete on-orbit checkout of the Aura spacecraft and instruments.**
2. **Capture, process, calibrate, and validate Aura data, and make this data available to the user community.**
3. **Produce 3-D global atmospheric surveys of environmentally important trace gases and aerosols. These surveys will address several critical societal issues:**
   a. The Earth's Ozone Shield is fundamental to protecting all life.

      Quantifying the change in stratospheric ozone in response to decreases in chlorofluorocarbons and increases in greenhouse gases, as well as extending the high precision measurements of global column ozone for use in trend detection.

      Mission success includes the global measurement of the vertical profiles of radicals, reservoirs and sources from the families of gases responsible for ozone depletion for > 2 years and measurement of column ozone trends to a precision of 1%/decade for > 3 years.

   b. The Earth's Climate responds to and affects changes in greenhouse gases and aerosols.

      Determining the linkage between climate change and changes in atmospheric constituents.

      Mission success includes determining the exchange of greenhouse gases between the stratosphere and troposphere, as well as mapping aerosols, water vapor, ozone, and clouds in the upper troposphere for > 2 years.

   c. The Earth's Air Quality is fundamental to public health.

      Determining how localized tropospheric pollution sources contribute to regional and global pollution.

      Mission success includes mapping and quantifying the transport and sources of tropospheric ozone, aerosols, carbon monoxide and nitrogen oxides for > 1 year.

   d. Oxidation controls the levels of ozone depleting gases, greenhouse gases, and air pollutants.

      Determining natural and anthropogenic influences on the global oxidizing power of the troposphere.

      Mission success includes characterization of the global distributions and sources of tropospheric ozone, carbon monoxide, methane, and nitrogen oxides for > 1 year.

Aura Spacecraft Subsystems

- Command and Data Handling (C&DH)
  - Four redundant Honeywell 1750A processors: Command and Telemetry Controller (CTC), Power Controller (PC), Guidance, Navigation and Control Controller (GNCC), and Instrument Support Controller (ISC)
    - » CTC utilizes 768K RAM and 512K EEPROM
    - » PC, GNCC, and ISC each utilize 256K RAM
  - MIL-STD-1553B data bus for housekeeping/engineering telemetry and low-rate HIRDLS and MLS science data; TAXI for high-rate OMIS and TES science data
  - One redundant FTS ultra-stable oscillators: USO-1 provides GIRD and spacecraft time and controller interrupts
  - Transponder Interface Electronics provides the command & telemetry interface to the transponders and distributes timing signals from the USO
  - Single Formatter-Multiplexer Unit/Solid State Recorder with redundant FMUs, SSR provides 104 GB (BOL) recording capacity (> 2 orbits)
- Thermal
  - Essentially passive system utilizing radiators and software or thermostatically controlled heaters
  - Variable conductance heat pipes (VCHPs) used for battery radiator

Aura Spacecraft Subsystems

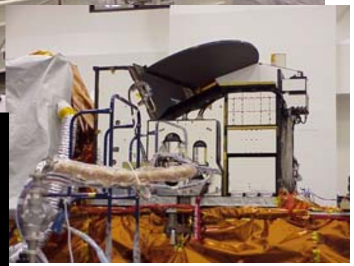
- Guidance, Navigation and Control (GN&C)
  - Three-axis stabilized, zero-momentum system with the following capabilities:
    - » Attitude control accuracy – better than 25 arc-seconds
    - » Attitude knowledge – 25 arc-seconds
  - Architecture consists of:
    - » Teldix reaction wheels (4 in a pyramid)
    - » Litton HRG (4 for 3 redundant)
    - » Ball 602 star trackers (2)
    - » Barnes coarse horizon sensor assembly (4 earth sensor “eyes” on a bracket)
    - » Ithaco torque rods (3) and three-axis magnetometers (2)
    - » NGST coarse sun sensors (4)
- Propulsion
  - Hydrazine blow-down system, utilizes Nitrogen as the pressurant
  - Four NGST designed dual-thruster modules with eight 1-lb thrusters (4 Pri, 4 Red)
  - TDRS designed propellant tank, filled to capacity of 231 kg at launch
  - 134 kg fuel required for 6-year mission, remaining 97 kg available for end of mission attitude control and de-orbiting

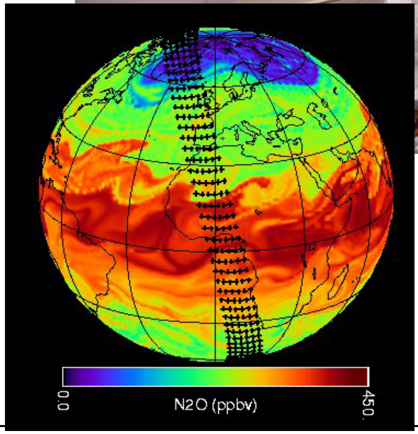
Aura Spacecraft Subsystems

- Communications
  - System compatible with both the SN and EPGN for S and X-Band communications with the following data rates:
    - » S-Band TLM: 1K, 4K, 16Kbps (and 524Kbps SSR playback of engineering)
    - » S-Band CMD: 125, 250, 1000bps, and 2Kbps
    - » X-Band DATA: 15Mbps Direct Broadcast, 150Mbps Direct Playback
  - Architecture consists of:
    - » Motorola (General Dynamics) 4^{th} generation TDRSS transponders (2) along with omni antennas (nadir and zenith decks) which can be cross-strapped via an RF switch for S-Band communications
    - » Cincinnati Electronics X-Band modulator (internally redundant) feeding Thompson Tubes TWTAs (2) and downlinking through a single earth coverage antenna for X-Band communications
- Electrical Power System (EPS)
  - Single NGST designed 160 amp-hour battery with 24 Eagle Picher cells (22 required)
  - Single NGST/Dutch Space designed solar array with 4600 watt output at EOL
  - Battery regulated bus with computer controlled charging
  - Secondary Converter Electronics provides conditioned power (29 ± 1 V) to instruments

High Resolution Dynamics Limb Sounder (HIRDLS)

- Infrared Limb-Scanning Radiometer; Measures IR Limb Emissions of Trace Gases and Aerosols
- 21 Channels; Spectral Range: 6-18 microns
- 2-axis Gimbaled Mirror Provides Scanning in Altitude and Azimuth With Periodic Views to Internal Blackbody and Space
- Optic Train Vibration Isolated from Bus Mechanical Disturbances
- Instrument Inertial Reference Unit Provides Knowledge of Vibration Isolated Optic Train WRT Bus
- Chopper Provides Alternating Views of Atmospheric Scene and Space View
- Instrument Developed Jointly by
  - **NASA**
    - **Lockheed Martin**
    - **University of Colorado, Boulder**
  - **Natural Environment Research Council (United Kingdom)**
    - **Oxford University**
    - **Rutherford Appleton Laboratory**





Simulated N2O field using a high resolution transport model.

1.25 km vertical resolution

Azimuth and Elevation Scanning

~8000 profiles/day

Microwave Limb Sounder (MLS)

- Passive Microwave Radiometer/Spectrometer; Measures Microwave Limb Thermal Emissions of Ozone Destroying Chemicals

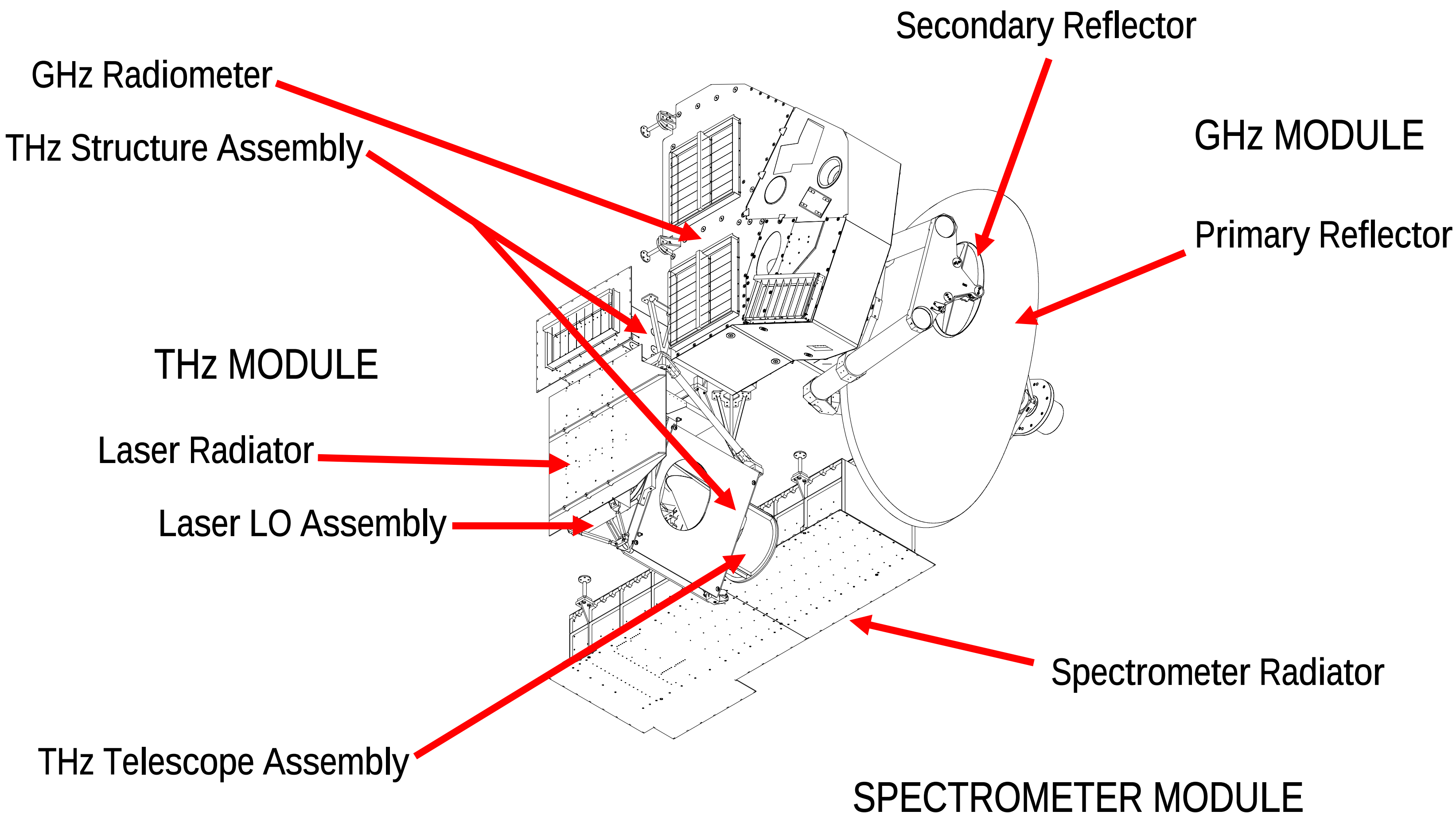
- GHz Module
  - **3-Reflector Antenna System**
  - **Radiometers for 118, 190, 240, and 640 GHz Measurements**
  - **Scan Mirror Views Limb, Internal Calibration Targets, and Cold Space**

- THz Module
  - **Scan Switching Mirror Views Limb and Cold Space**
  - **Radiometer for 2.5 THz Measurements**

- Spectrometer

- Developed by JPL

Microwave Limb Sounder (MLS)



Ozone Monitoring Instrument System (OMIS)

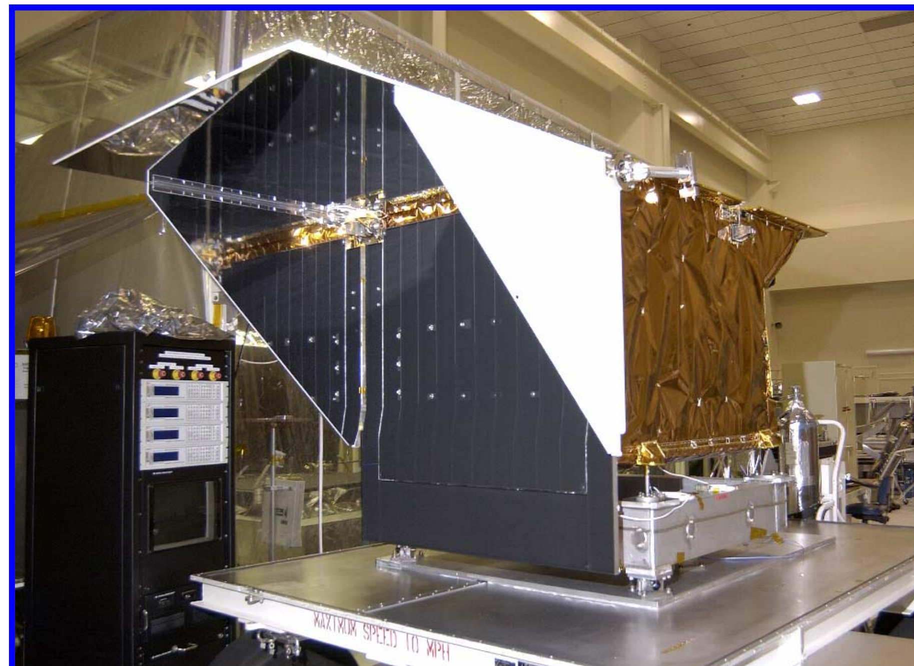
- **Non-Scanning, Nadir-Viewing Imaging Spectrometer; Measures Solar Backscatter Radiation**
- **Optical Assembly (OA)**
  - Wide-Field Telescope Feeds Two Imaging Grating Spectrometers
  - Two Charge Coupled Device (CCD) Detectors; One Per Spectrometer
  - Visible Range: 300 – 500 nm
  - UV Range1: 270 – 314 nm; UV Range2: 306 – 380 nm
  - On-Board Calibrators
- **Electronics Assembly (EA)**
- **Interface Adaptor Module (IAM)**
- **Ozone Monitoring Instrument (OMI) Contributed by Netherlands Space Agency (NIVR) and Finnish Meteorological Institute (FMI)**

•OMI Developed by Dutch Space and TNO-TPD; OMI Electronics developed by Finnish Industry

•IAM Developed by Northrop Grumman-STS

Tropospheric Emission Spectrometer (TES)

- High-Resolution Infrared-Imaging Spectrometer; Connes-type 4-port Fourier Transform Interferometer
- Measures and Profiles All Infrared-Active Molecules Present in the Earth’s Lower Atmosphere (0 – 30 Km)
- Four Detector Arrays (16 Pixels Each); 3.3 – 15.4 Microns
- 2-Axis Gimbaled Pointing Mirror
- Developed by Jet Propulsion Laboratory (JPL)



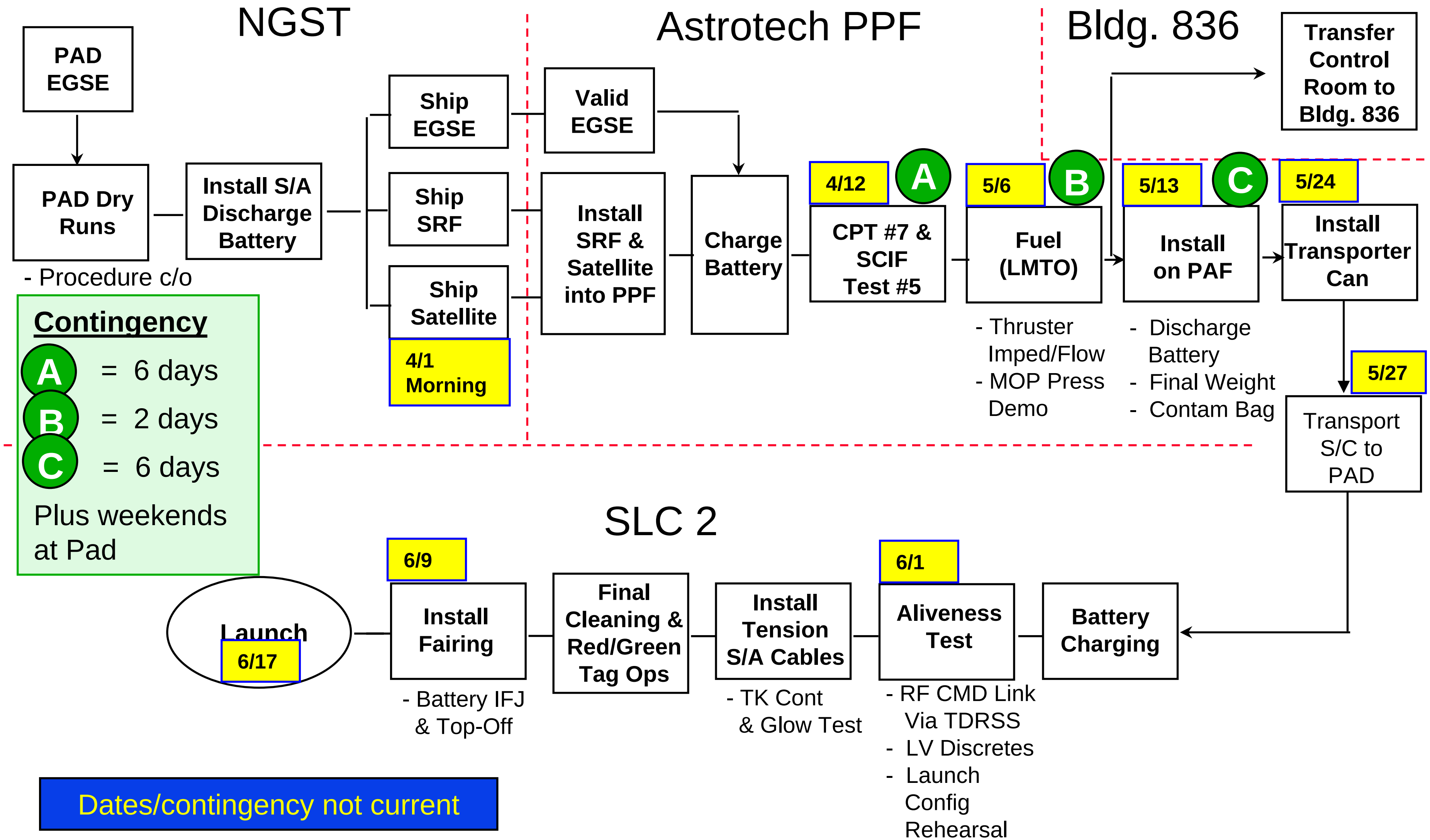
Aura Launch Configuration

- C&DH
  - ✓ CTC A-on, B-on
  - ✓ GNCC A-on, B-off
  - ✓ PC A-on, B-off
  - ✓ ISC A-on, B-off
  - ✓ TIE A-on, B-off
  - ✓ FMU/SSR A-on, B-off
  - ❖ USO off for launch
- GN&C
  - ❖ All avionics, sensors, and actuators off for launch

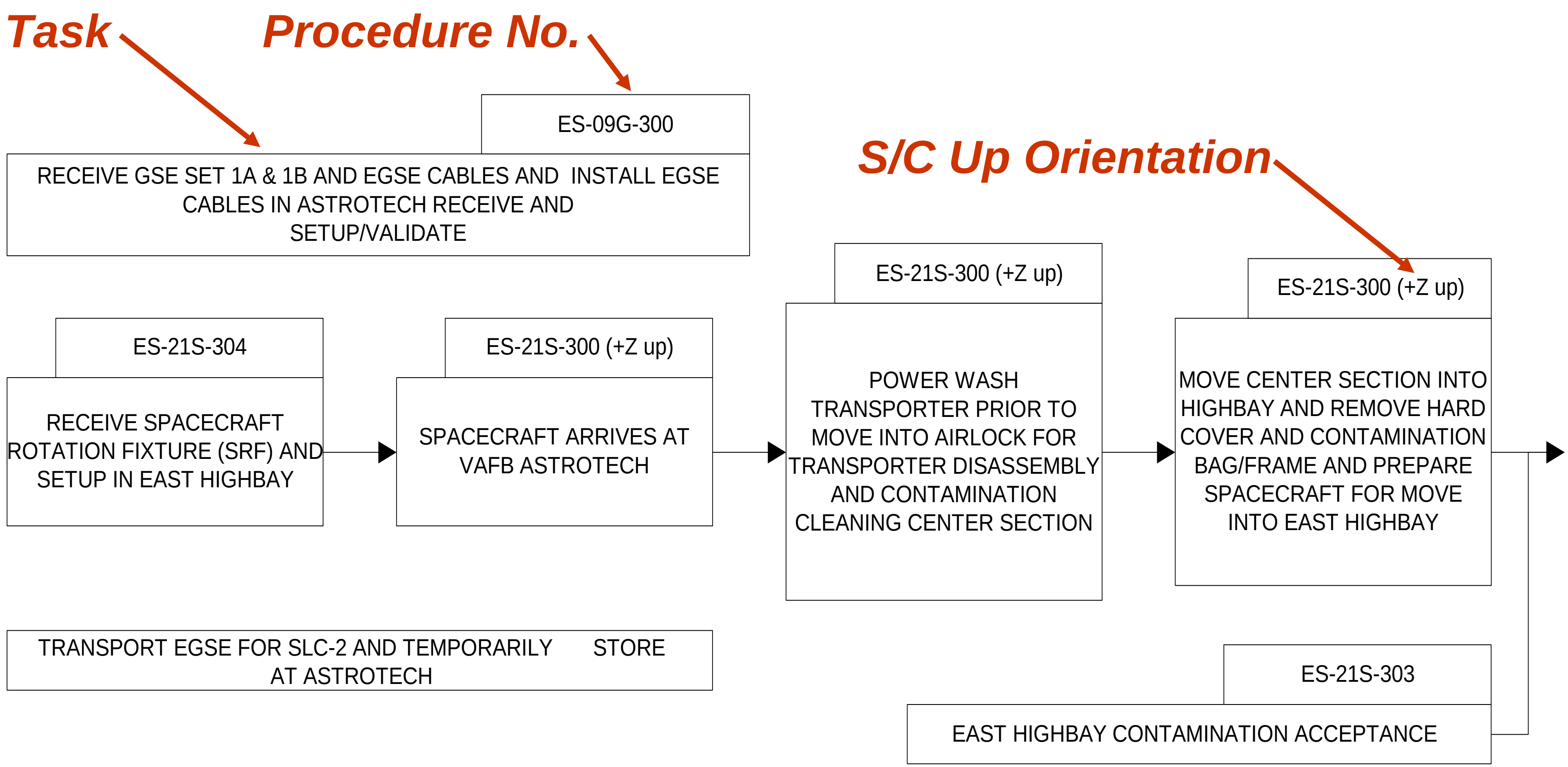
  {prior to separation, the IRU is powered on}
- COMM
  - ✓ S-Band XPNDR-A Rcvr-on, Xmtr-off
  - ✓ S-Band XPNDR-B Rcvr-on, Xmtr-off
  - ❖ X-Band – all H/W off for launch

  {prior to separation, the S-Band Xmtrs are powered on}
- EPS
  - ✓ Battery fully charged
  - ✓ PCE on
  - ✓ AREs 1-6 on
  - ✓ ACEs 1-2 on
  - ❖ HDEs 1 – 2 A&B off for launch
  - ❖ SCEs 4-6 off for launch
  - ❖ TKEs A/B off for launch
  - ❖ Solar Array stowed
- Propulsion
  - ✓ Pressure Transducer on
  - ❖ All other H/W off for launch
- Thermal
  - ❖ All heaters off for launch
- Instruments
  - ❖ All instruments off for launch

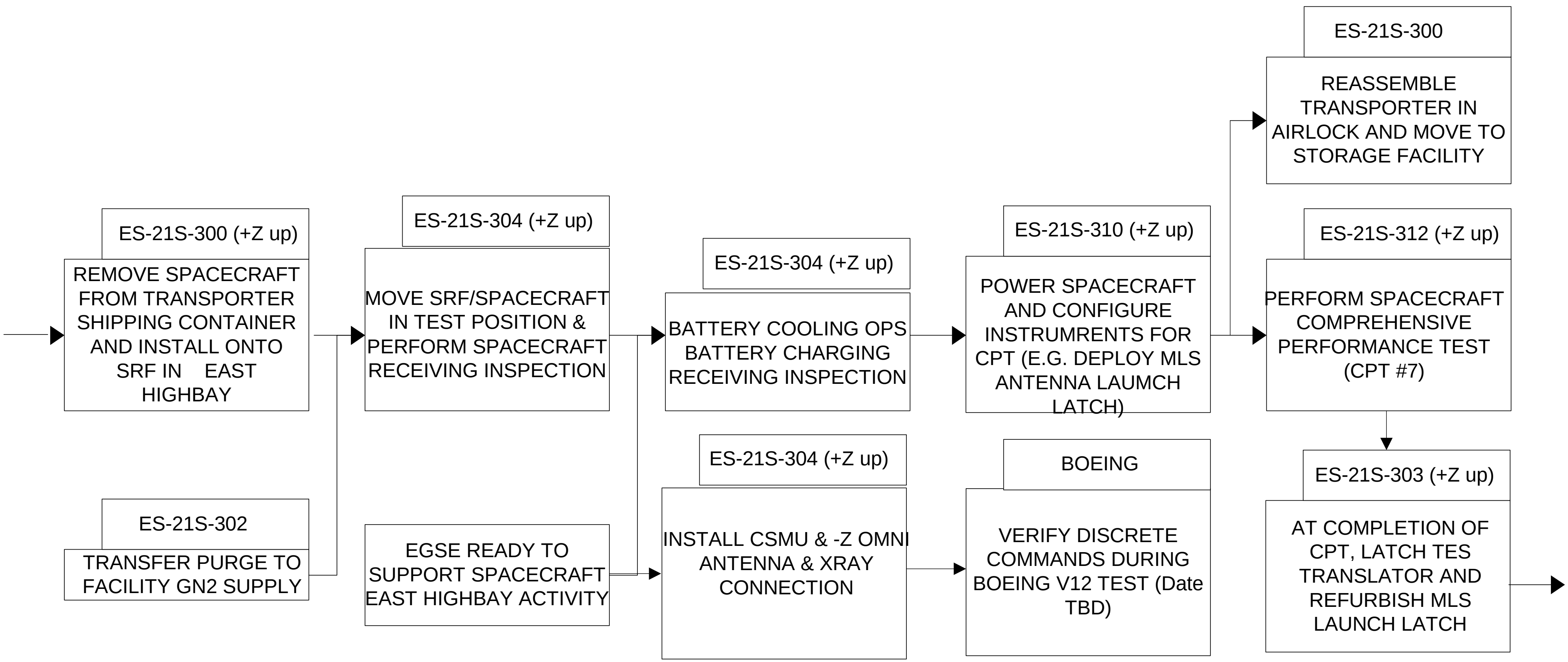
Launch Flow Overview



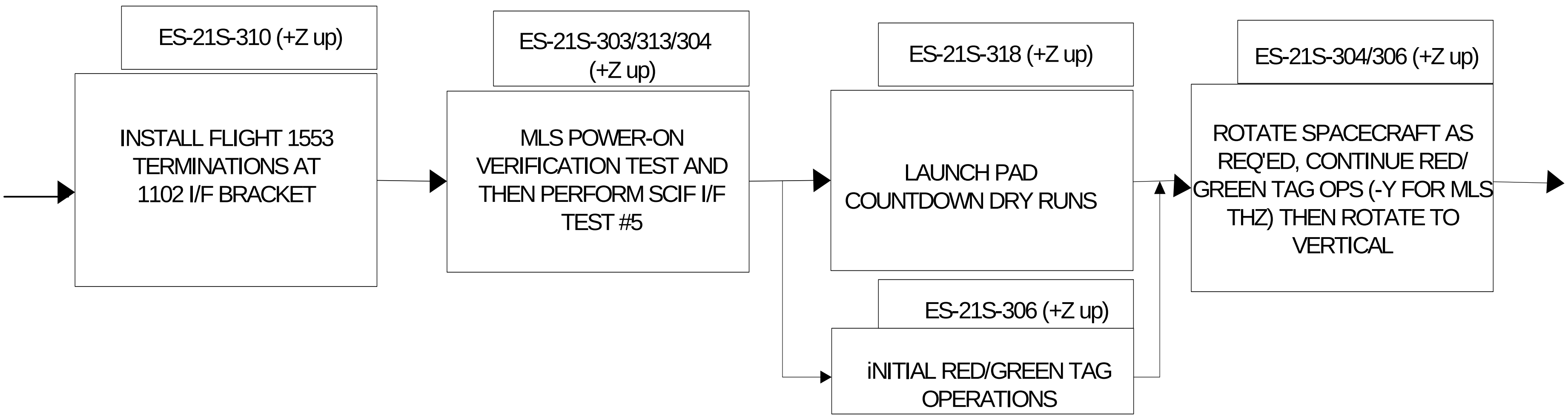
EOS Aura Launch Flow



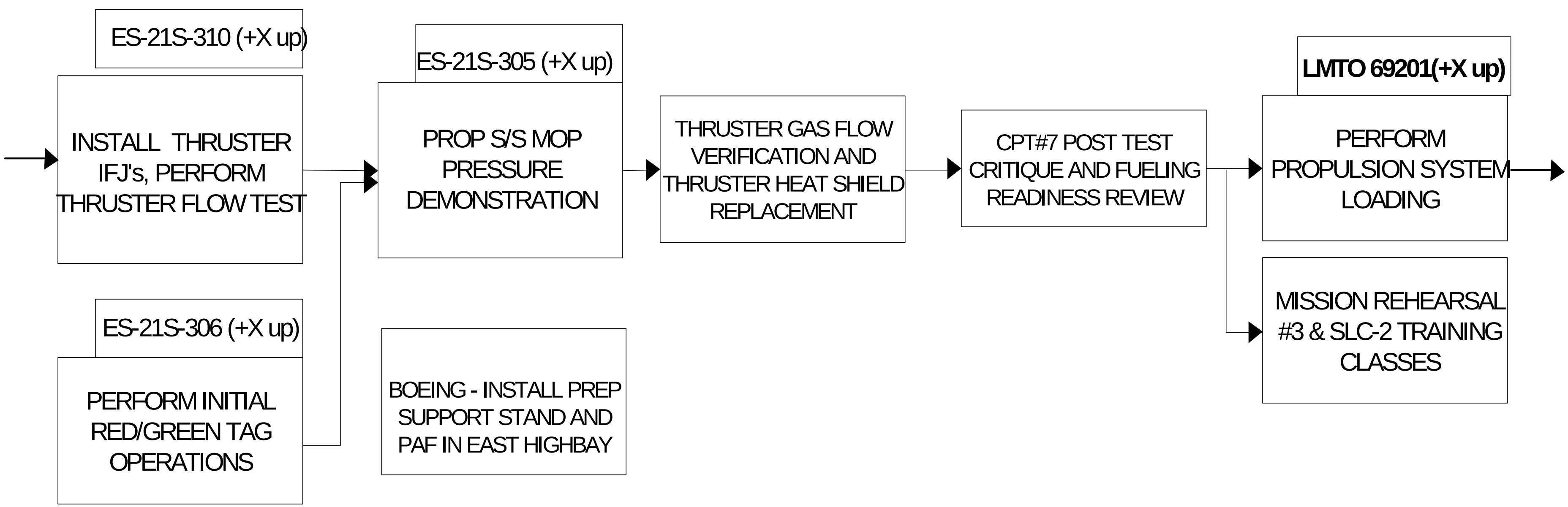
EOS Aura Launch Flow (Continued)



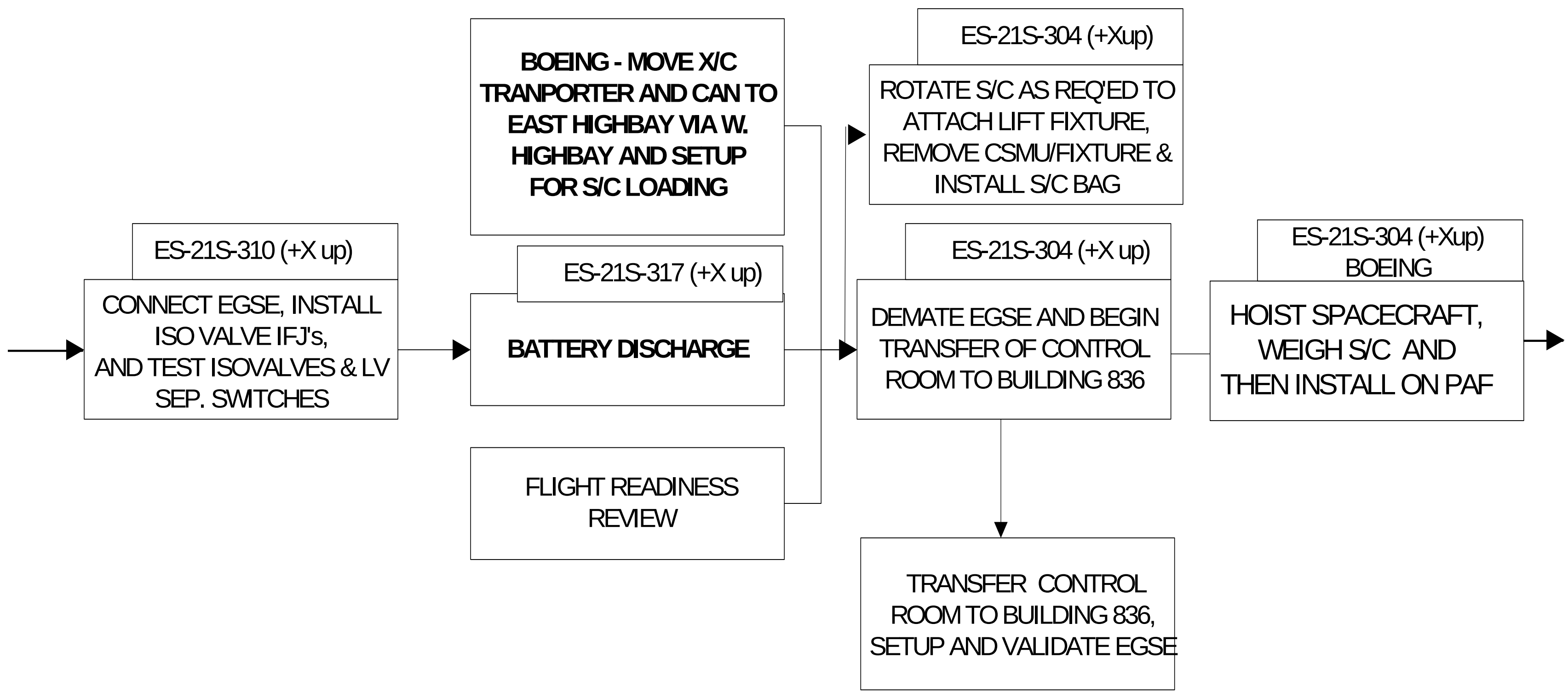
EOS Aura Launch Flow (Continued)



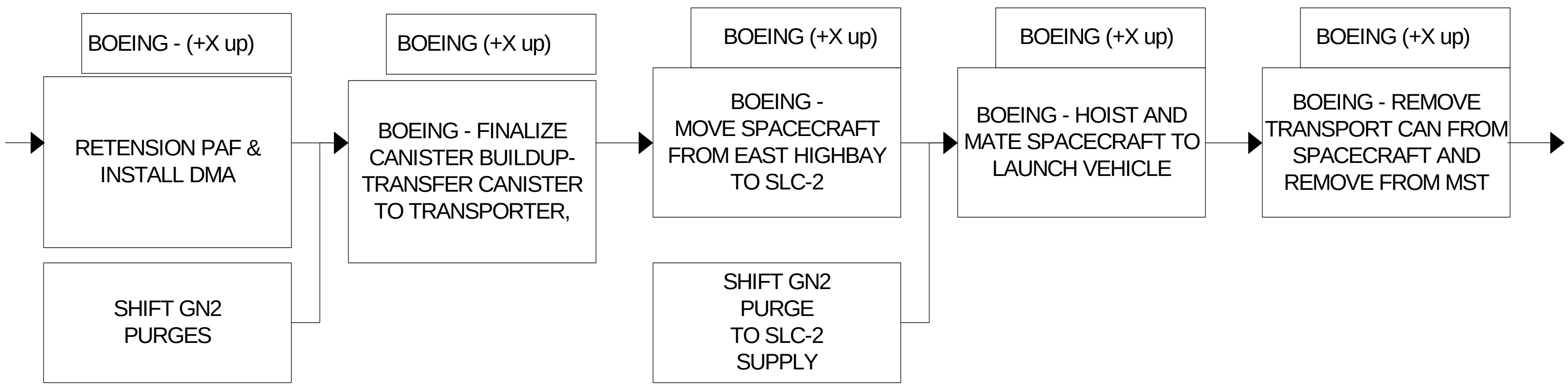
EOS Aura Launch Flow (Continued)



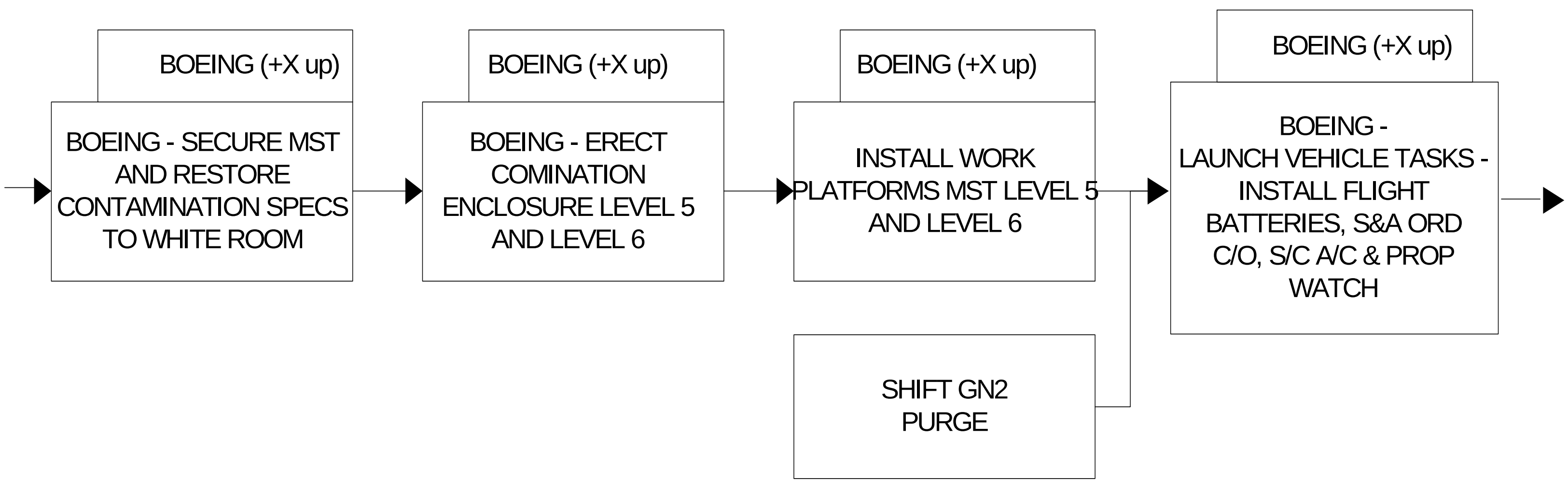
EOS Aura Launch Flow (Continued)



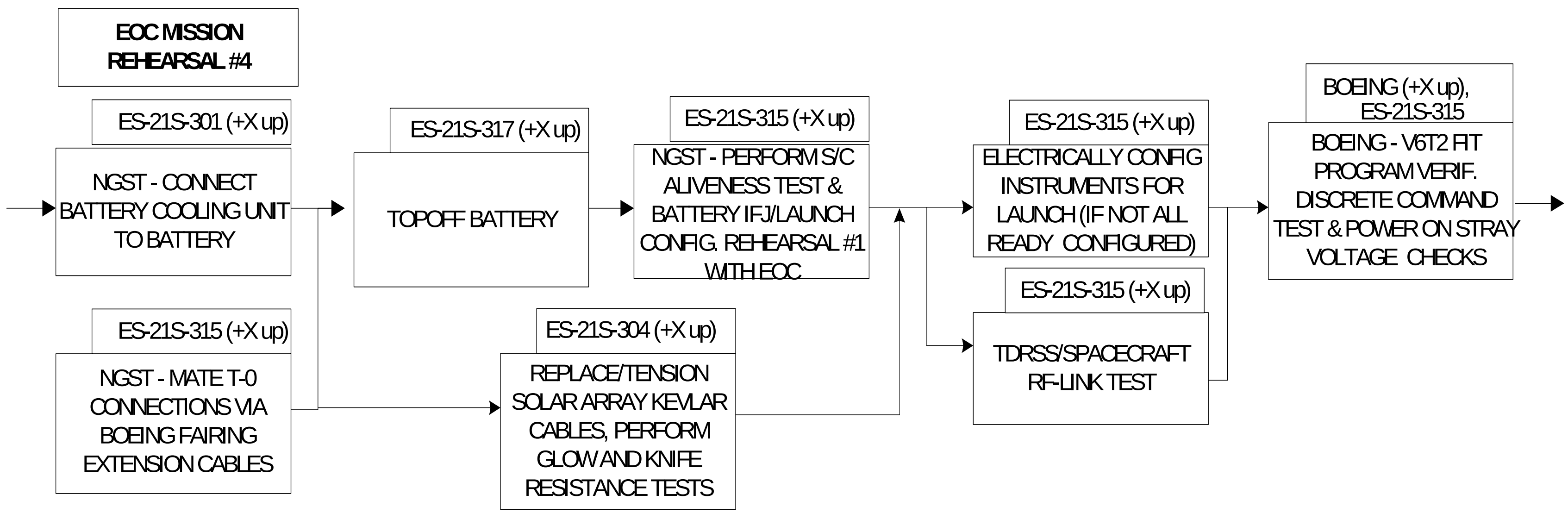
EOS Aura Launch Flow (Continued)



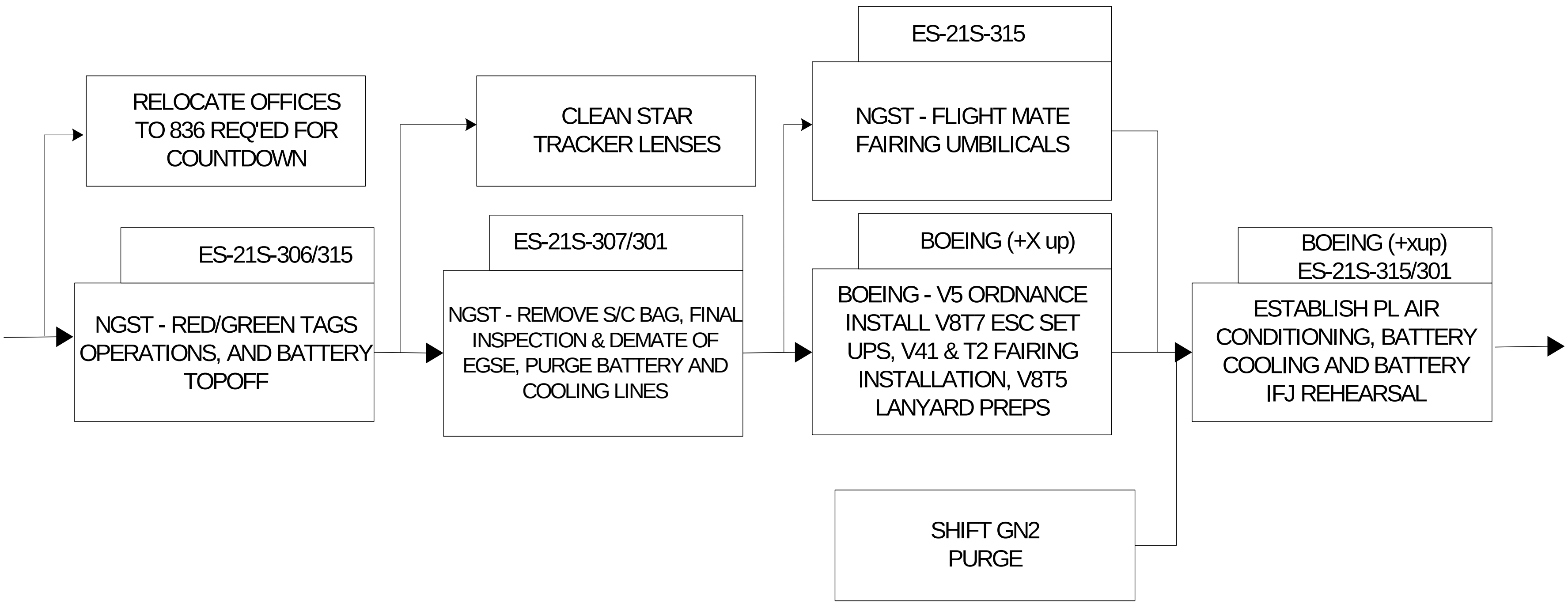
EOS Aura Launch Flow (Continued)



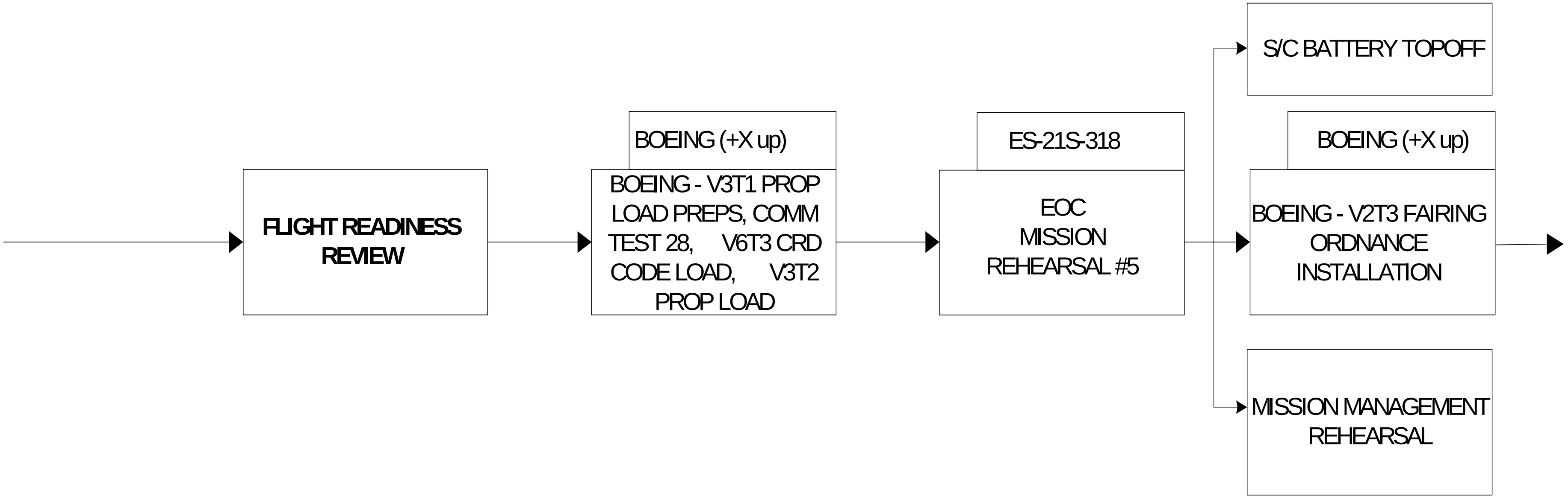
EOS Aura Launch Flow (Continued)



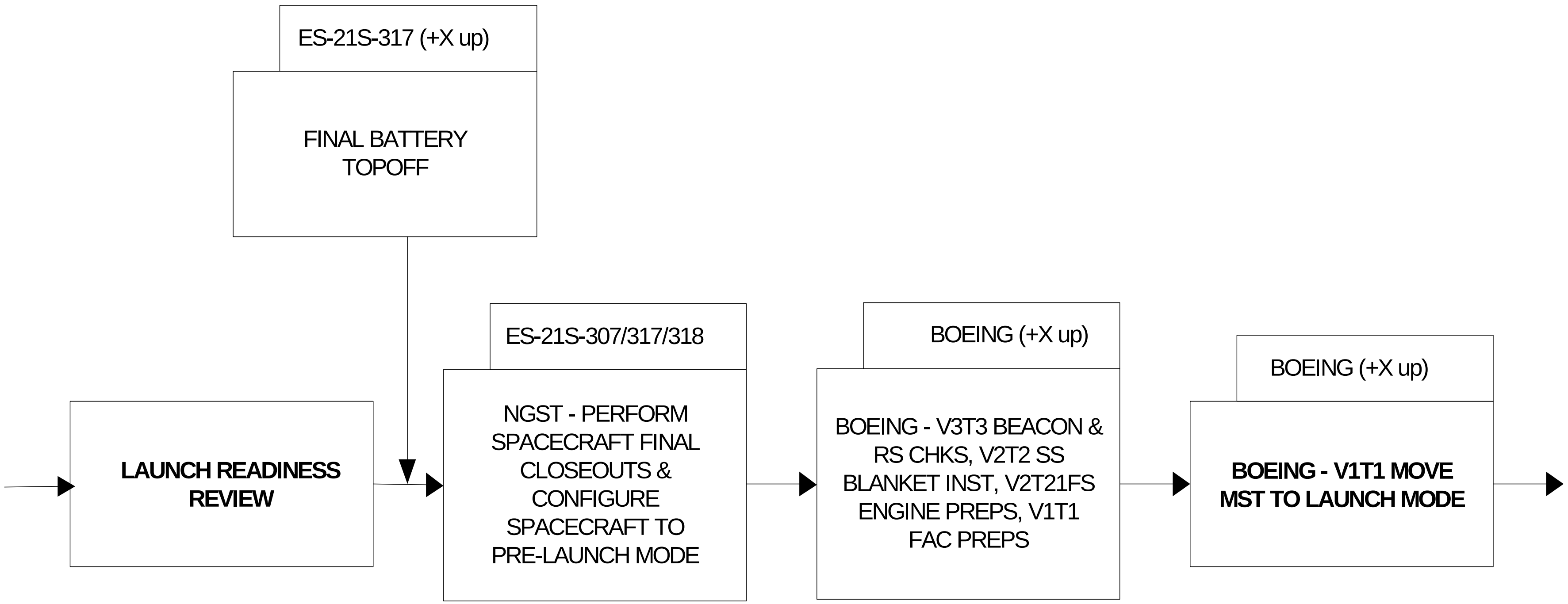
EOS Aura Launch Flow (Continued)



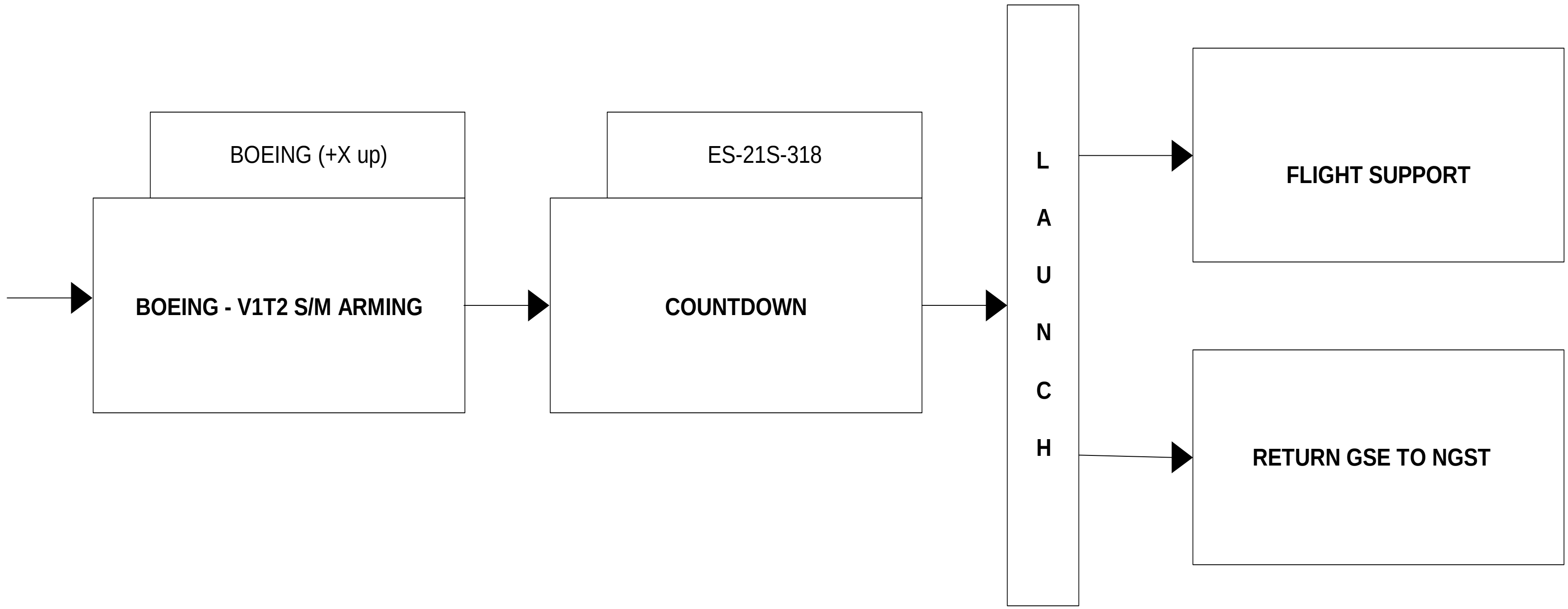
EOS Aura Launch Flow (Continued)



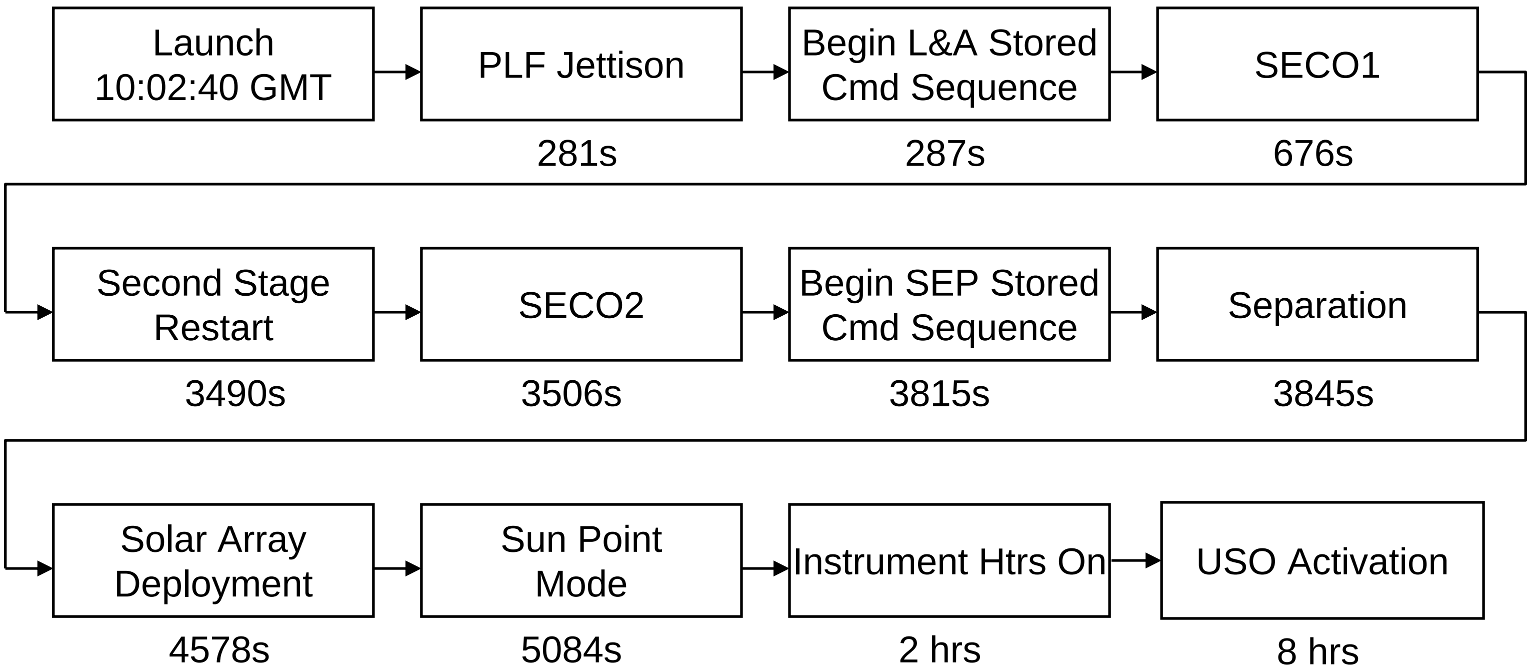
EOS Aura Launch Flow (Continued)



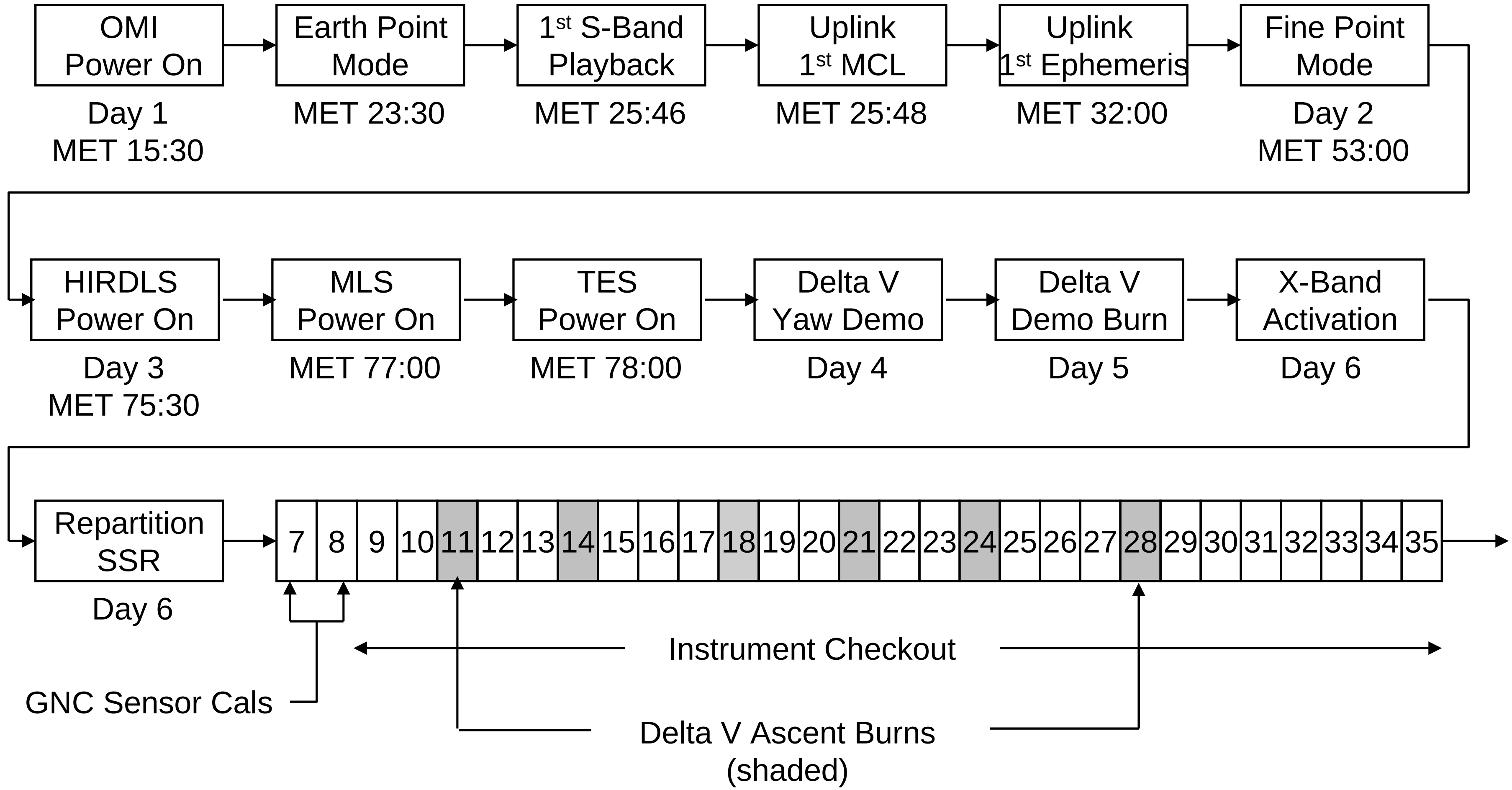
EOS Aura Launch Flow (Continued)



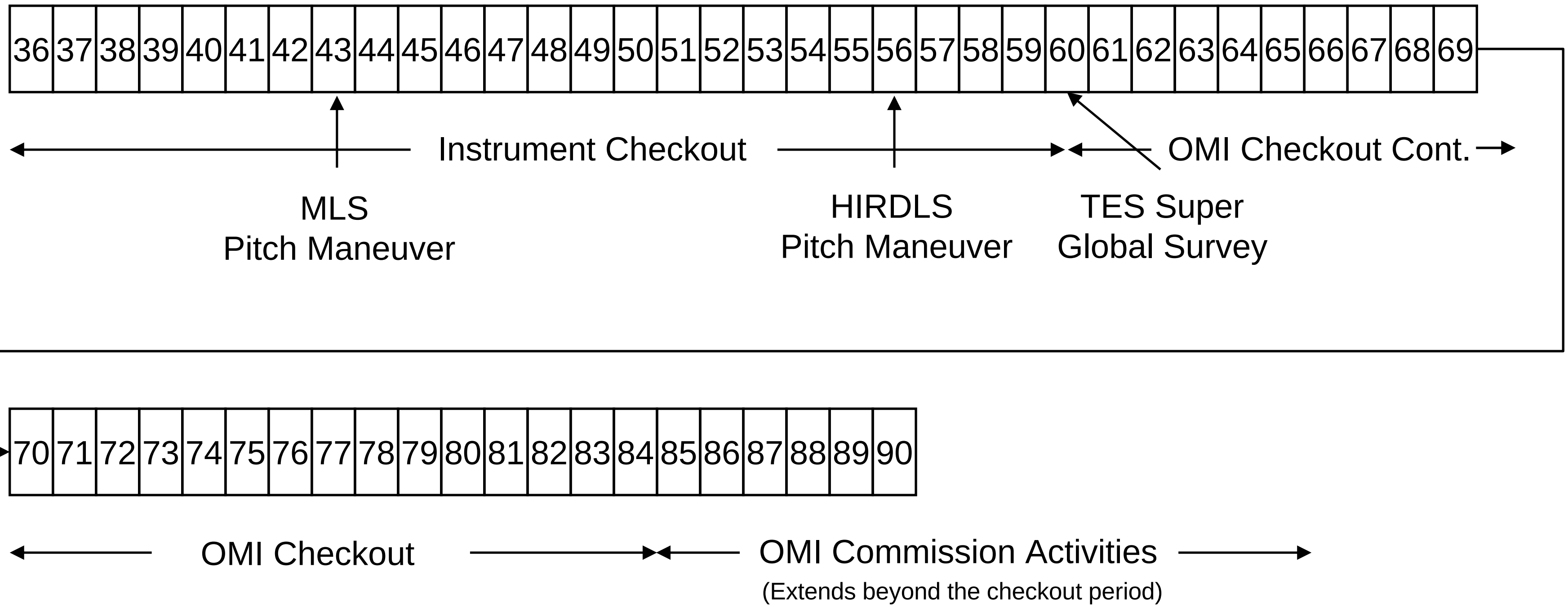
Aura Launch, Activation & Checkout – Day 0



Aura Launch, Activation & Checkout – Days 1-35



Aura Launch, Activation & Checkout – Days 36-90



Aura ODA Chronology

Event	**Date**
Aura delta-CDR	Sept 2000
Aura ORSAT Analysis complete	July 2001
Aqua Launched	May 2002
ODA Report Submittal to HQ	Feb 2003
JSC Assessment #1 Returned	June 2003
Resubmittal of ODA Report to HQ	Nov 2003
JSC Assessment #2 Retrieved	April 2004

JSC Assessment Results

- **February 2003**
  - Full compliance with 1740.14 (with one exception)
    - Requested more info for assessing guideline 4-2 that requires release of all stored energy and EOM
- **February 2004**
  - Changed guideline 4-1 to non-compliant
    - requiring probability analysis of on-orbit explosion potential
  - Found non-compliance in guideline 4-2
    - due to non-ventable 150 psi residual nitrogen pressurant
  - Changed population model and re-entry date assumptions used in the original analysis
    - creating non-compliance with guideline 7-1

Guideline 4-1

- **Background**
  - Requires an assessment of the probability of explosion on-orbit during normal operations
  - A qualitative assessment was provided in the initial submission
  - JSC approved initial qualitative assessment
  - Recent JSC evaluations are expecting more qualitative assessments of the risk of on-orbit explosion
- **Current Status**
  - Turnaround of this type of assessment is 2-3 weeks minimum

Guideline 4-2

- **Background**
  - Requires minimization of stored energy to reduce the probability of orbital debris generation after end-of-mission
  - Aura report identified discharge of batteries, rundown of the momentum wheels, depletion of the remaining hydrazine in the prop tank in a de-orbit burn, etc. would be performed at EOM.
  - Remaining nitrogen pressurant is not releasable by design.
- **Current Status**
  - Substantial risks and costs are involved in any type of modification of the propulsion system to support a pressurant dump at EOM.
  - The original qualitative assessment that the probability of debris generation is low risk was not itself questioned
    - Residual pressurant is relatively inert gaseous nitrogen at a fraction of the tank burst pressure
    - Temperature swings of the propulsion tank located inside the spacecraft structure are mitigated by MLI and surrounding spacecraft structure.
    - Pressure release most likely to occur at re-entry, and is not a threat to orbital debris generation.

Guideline 7-1

- **Background**
  - The guideline requires a less than 1:10,000 probability of casualties with an uncontrolled re-entry, a number based on a Debris Casualty Area (DCA) of 8 square meters (m^2).
  - Aura's JSC-approved ORSAT analysis (completed July '01) derived a probability of 1:10,540 for re-entry in year 2001 with a DCA=10.49 m^2
  - JSC approved this in their February 2003 assessment.
- **Current Status**
  - In the Feb 2004 assessment by JSC, Aura DCA exceeds allowable for re-entry in 2035 by a factor of 1.29, for a casualty probability of 1:7,750
  - Normally, the ODA analysis is approved at CDR and is not revisited so close to a launch. Revisiting the analysis on numerous other missions could call into question those designs as well.
  - To reduce the DCA enough to meet the guideline would require removal/rebuild of one or more of the Aura instruments.
  - To approve a waiver and launch as-is, as was done on Aqua, would mean that the casualty odds would remain 29% over the guideline.

IV&V Scope
(Critical Functions List)

IV&V Objectives	S/C	HIRDLS	TES	IAM	MLS
Total Software Functions	52	42	19	18	20
Confirm that software test planning was adequately defined to verify that the software was properly tested and met specified performance	**52**	**42**	**19**	**18**	**20**
Confirm that software requirements have been allocated to tests	**52**	**42**	**19**	**18**	**20**
Confirm that requirements associated with critical functions were fully addressed by the assigned test(s), and upon successful completion, the requirements could be considered fully verified	**25**	**26**	**10**	**10**	**18**
Confirm that test results were as expected for the most critical functions	**4**	**26**	**2**	**2**	**16**
Confirm that testing demonstrated that the software performs reliably under realistic and stressful mission scenarios	**11**	**25**	**7**	**9**	**16**

IV&V Activities

The goal of the IV&V effort is to verify that the Aura test program is adequately defined and verifies critical functions of the Aura spacecraft and instrument software

Confirm that software test planning is adequately defined to verify that the software is properly tested and meets specified performance

Activities

- Verify test plans and related test planning documentation are sufficient to validate software requirements
- Verify test case definition inputs, expected results, and evaluation criteria comply with test plans and objectives
- Verify that regression tests are sufficient to determine that the software is not adversely affected by changes
- Verify that applicable hazard and safety analyses adequately identify software requirements for the control of hazards and verify that test plans and requirements adequately validate that the software is capable of controlling hazardous conditions

Confirm that software requirements have been allocated to tests

Activities

- Verify consistency between SRD and traceability matrices
- Verify consistency between traceability matrices and test case documentation
- Verify that requirements are traced to test cases

Confirm that requirements associated with critical functions are fully addressed by the assigned test(s), and upon successful completion, the requirements can be considered fully verified

Activities

- Assess the appropriateness of specified requirements qualification methods
- Verify that software requirements are adequately addressed by the test cases that they are traced to
- Verify that acceptance test criteria adequately addresses requirements

Confirm that test results are as expected for the most critical functions

Activities

- Verify successful execution of test cases
- Verify acceptance test criteria was met

Confirm that testing demonstrates that the software can perform reliably under realistic an stressful mission scenarios

Activities

- Verify that interface tests are sufficiently defined to verify requirements associated with critical system interfaces
- Verify that performance tests are sufficiently defined to test both nominal and off-nominal conditions
- Verify that Aura functional end-to-end tests are sufficiently defined to test system requirements and operational needs